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National Profile on Commercially Generated Low-Level Radioactive Mixed Waste

Prepared by
J. A. Klein, J. E. Mrochek, R. L. Jolley, I. W. Osborne-Lee, A. A. Francis, T. Wright

Oak Ridge National Laboratory

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U.S. Nuclear Regulatory Commission

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Abstract

This report details the findings and conclusions drawn from a survey undertaken as part of a joint U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency-sponsored project entitled "National Profile on Commercially Generated Low-Level Radioactive Mixed Waste." The overall objective of the work was to compile a national profile on the volumes, characteristics, and treatability of commercially generated low-level mixed waste for 1990 by five major facility categories—academic, industrial, medical, and NRC-/Agreement State-licensed government facilities and nuclear utilities. Included in this report are descriptions of the methodology used to collect and collate the data, the procedures used to estimate the mixed waste generation rate for commercial facilities in the United States in 1990, and the identification of available treatment technologies to meet applicable EPA treatment standards (40 CFR Part 268) and, if possible, to render the hazardous component of specific mixed waste streams nonhazardous. The report also contains information on existing and potential commercial waste treatment facilities that may provide treatment for specific waste streams identified in the national survey. The report does not include any aspect of the Department of Energy's (DOE's) management of mixed waste and generally does not address wastes from remedial action activities.

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Executive Summary

This report details the findings and conclusions drawn from a survey undertaken as part of a joint U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency-sponsored project entitled "National Profile on Commercially Generated Low-Level Radioactive Mixed Waste." The overall objective of the work was to compile a national profile on the volumes, characteristics, and treatability of commercially generated low-level mixed waste for 1990 by five major facility categories—academic, industrial, medical, and NRC-/Agreement State-licensed government facilities and nuclear utilities. Included in this report are descriptions of the methodology used to collect and collate the data, the procedures used to estimate the mixed waste generation rate for commercial facilities in the United States in 1990, and the identification of available treatment technologies to meet applicable EPA treatment standards (40 CFR Part 268) and, if possible, to render the hazardous component of specific mixed waste streams nonhazardous. The report also contains information on existing and potential commercial waste treatment facilities that may provide treatment for specific waste streams identified in the national survey. The report does not include any aspect of the Department of Energy's (DOE's) management of mixed waste and generally does not address wastes from remedial action activities.

The national survey consisted of a series of steps which included: (1) selecting a total number of facilities to be sampled, based on an expected 25% nonresponse rate and a 10% relative standard error; (2) sending out a detailed questionnaire to a number of randomly selected facilities; (3) accumulating and compiling the responses in an appropriate format and database; (4) estimating the national generation rates based on multiplying the "raw" mixed waste generation data by weighting factors to correct for the fraction of the facilities in each group that were sent questionnaires. The final sample sizes were selected to achieve a relative standard error of 10% to provide a conservative survey design and to provide a measure of protection for uncorrectable factors such as incorrect and missing data.

The survey target population (survey frame) included a total of 2,936 facilities. The random sample selected from the target population consisted of 1,323 facilities. Data from 1,016 completed mixed waste survey questionnaires, including 21 facilities that reported they were out of business (77% response rate), received by Oak Ridge National Laboratory indicate that approximately 81,000 ft^3 of low-level radioactive mixed waste was generated in the United States in 1990 by those facilities surveyed. Approximately 63% of this reported volume was liquid scintillation fluids (LSF).

Using the weighting factors described previously to generate a statistically valid estimate of the 'national' profile, the survey estimates that approximately 140,000 ft^3 of commercial low-level radioactive mixed waste was generated nationally in 1990 and that nearly 72% was LSF. In addition, an estimated 75,000 ft^3 of commercial low-level mixed waste was in storage for various reasons as of December 31, 1990. The industrial category was estimated to be the largest generator and also the largest accumulator of mixed waste. Industrial facilities generated over 36% of the mixed waste generated in 1990 and accounted for 57% of the mixed waste in storage as of December 1, 1990. Data received from 97% of the operating nuclear utilities in the country indicated that they generated less than 10% of the estimated total 1990 generation rate for commercial mixed waste.

Although Compact/State and Hazardous Waste Stream data are presented, it should be emphasized that the profile was generated to be statistically valid only at the national level and only for the major facility categories. It is estimated that the overall accuracy of the projected

commercial mixed waste generation rates and waste in storage are well within the objective of the study that was to be, at the 95% confidence level, within a factor of 2. Estimations of commercial mixed waste generation and storage at the state or regional level may be less reliable, mainly due to fewer samples in these substrata.

The survey sets upper and lower bounds on the volume of mixed waste that is untreatable under current technologies by making the simplifying assumption that LSF, oil, organic (not halogenated), and corrosive mixed wastes are treatable. Deducting the wastes that are assumed to be treatable from the estimated national total mixed waste generation rate leaves about 18,500 ft^3 of mixed waste that is untreatable. Thus, with this as an upper bound and the estimated 5,000 ft^3 of reported currently untreatable mixed waste as the lower bound, the untreatable mixed waste ranges from 3.5 to 13.3% of the estimated 1990 national generation rate of 140,000 ft^3. Please note, however, that the capacity to treat all of the so-called "treatable" mixed waste may not be available.

A broad spectrum of commercially generated low-level radioactive mixed waste streams are generated by the facilities surveyed including LSFs, halogenated and unhalogenated organics, wastes contaminated with toxic metals, and acidic and basic corrosives. These mixed wastes present a need for specific waste treatment services, including incineration, stabilization, chemical treatment, and recovery/reuse processes. Four commercial companies, NSSI (Houston, TX), DSSI (Kingston, TN), Quadrex (Gainesville, FL), and RAMP (Denver, CO), currently offer treatment services for mixed waste. Two other companies, SEG (Oak Ridge, TN) and Envirocare (Salt Lake City, UT), may offer mixed waste treatment services in the near future. Comparing estimated demand for commercial mixed waste treatment services (1990 generation rate plus total mixed waste in storage at the end of 1990) with available treatment capacity in specific mixed waste categories indicated that sufficient capacity seems to exist for more than 95% of all mixed waste except chlorinated fluorocarbons (CFCs), lead shielding and other waste contaminated with solid lead, and mercury-contaminated equipment and debris. The shortfall in commercial mixed waste treatment capacity amounts to about 12,000 ft^3. Currently operating commercial treatment facilities may be able to handle nearly all of the commercial mixed waste generated, based on 1990 generation data, but significant additional capacity must be developed to address the total demand which consists of not only the annual generation rate but also the mixed waste in storage at the end of 1990. In addition, this comparison does not include current and future demands that the noncommercial generators (i.e., the DOE) will have for commercial mixed waste treatment services. DOE's demand for commercial mixed waste treatment may affect the availability of these services to commercial generators.

Abbreviations

ACURI ..... Appalachian Compact Users of Radioactive Isotopes
AEA ..... Atomic Energy Act of 1954, as Amended
BDAT ..... Best Demonstrated Available Technology
CFC ..... Chlorinated Fluorocarbons
Cd ..... Cadmium and Cadmium-containing Materials
Corr ..... Corrosive Materials
Cr ..... Chromium and Chromium-containing Materials
DOE ..... U.S. Department of Energy
EEI ..... Edison Electric Institute
EPA ..... U.S. Environmental Protection Agency
Hg ..... Mercury and Mercury-containing Materials
HSWA ..... Hazardous and Solid Waste Amendments of 1984
IDB ..... Integrated Data Base
LDR ..... Land Disposal Restrictions (40 CFR Part 268)
LLRW ..... Low-Level Radioactive Waste
LLRWPAA ..... Low-Level Radioactive Waste Policy Amendments Act of 1985, as Amended
LSF ..... Liquid Scintillation Fluid
NEPA ..... National Environmental Policy Act of 1969
Org-Cl ..... Chlorinated Organics
Org-Fl ..... Fluorinated Organics
Org-Other ..... Organics Other Than Those Specifically Identified
ORNL ..... Oak Ridge National Laboratory
MW ..... Low-Level Radioactive Mixed Waste
NARM ..... Naturally Occurring or Accelerator-Produced Radioactive Material
NRC ..... U.S. Nuclear Regulatory Commission
Pb ..... Lead and Lead-containing Materials
RCRA ..... Resource Conservation and Recovery Act of 1976, as Amended
TCC . Host State Technical Coordinating Committee for Low-Level Radioactive Waste Disposal

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We would like to take this opportunity to express our appreciation to individuals without whom the completion of this project would not have been possible. These included University of Tennessee Environmental Law students — Shari Tayloe, Julie Martin, Kevin Townsel, Greg Oakley, and Larry Wallace for making the hundreds of follow-up telephone calls persuading facilities to respond to the survey; ORNL Biomedical and Environmental Information Analysis staff members — Mary Francis for database construction, organization and supervision, Karen Weaver and Cynthia Seiber for data entry, Mychal Manie for computer programming, and Gerry Danford for document tracking and quality assurance checking.

In addition, we would like to acknowledge the cooperation of members of Appalachian Compact Users of Radioactive Isotopes (ACURI) and its executive secretary, John Vincenti, for agreeing to participate in the pretest of the national survey. The Edison Electric Institute (EEI) is recognized for urging its members to complete their survey forms. In addition, the following compacts and states allowed us access to unpublished information they had on mixed waste generation in their compact or state: Appalachian Compact, Massachusetts, New York, Southeastern Compact, Southwestern Compact, and Texas. The ORNL study team would especially like to acknowledge the vital input of Chad Glenn of the Nuclear Regulatory Commission and Jared Flood of the Environmental Protection Agency who initially were the primary sponsor contacts involved with this program.

NATIONAL PROFILE ON COMMERCIALLY GENERATED LOW-LEVEL RADIOACTIVE MIXED WASTE

1 Introduction

1.1 Objective of the National Profile

The objective of this U.S. Nuclear Regulatory Commission- (NRC-) and U.S. Environmental Protection Agency- (EPA-) sponsored project was to compile a national profile on the volumes, characteristics, and treatability of commercially generated low-level radioactive mixed waste . The information collected and assembled in this project may be used by NRC, EPA, and the states to make decisions regarding the management and disposal of commercially generated mixed waste. The project did not encompass mixed waste generated by the government [i.e., Department of Energy (DOE)] since that universe of mixed waste had been previously estimated by DOE. This project did not specifically attempt to address cleanup wastes from remedial action activities although information obtained from generators performing these activities was not excluded.

1.2 Definitions

For the purposes of this project, mixed waste is defined as "waste that satisfies the definition of low-level radioactive waste (LLRW) in the Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA) and contains hazardous waste that (1) is listed as hazardous waste in Subpart D of 40 CFR Part 261 or (2) causes the LLRW to exhibit any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261."

The LLRWPAA defines LLRW as "radioactive material that (a) is not high-level radioactive waste, spent nuclear fuel, or byproduct material as defined in section 11e. (2) of the Atomic Energy Act of 1954 (AEA) i.e., uranium or thorium mill tailings and (b) NRC classifies as LLRW consistent with existing law and in accordance with (a)."

In addition, the following were included in the definition of hazardous waste for the purposes of the National Profile:

- Oils and oil sludges. These wastes are included in the survey because they may be considered hazardous under the RCRA for the "Toxicity Characteristic" or may be listed as hazardous or may be characteristically hazardous under state law.[a]
- Other wastes regulated as "hazardous wastes" solely under state law, but not under the Federal RCRA definition of hazardous waste.

Commercially generated low-level radioactive mixed waste, for the purposes of the National Profile, includes all mixed waste generated by NRC- or Agreement State-licensed facilities that would normally send any LLRW to one of the three existing LLRW disposal facilities. This definition would, therefore, include all generators of mixed waste except the DOE facilities.

Mixed waste generators include NRC- and Agreement State-licensed nuclear facilities and have been defined for this study to be nuclear utilities, medical, academic, industrial, and NRC/Agreement State-licensed government facilities. Individual generators chose the generator category that best described their mixed waste activities when completing the questionnaire. The term "nuclear utility" is equivalent to "nuclear power plant," "power plant," and "nuclear reactor facility" in this report. The "industrial" category includes facilities such as manufacturing, research and development, decontamination and waste reduction, sealed source users, waste brokers, nuclear fuel cycle other than reactors, and commercial radiopharmacies.

1.3 Work Performed

The project consisted of the following eight tasks:

1. Evaluation of existing available information on mixed waste from past surveys conducted by host states, compacts or other parties; summarizing the results; and identifying the lessons learned from past survey reports.
2. Determination of the adequacy of these existing data to estimate and project the volumes, characteristics and treatability of commercially generated mixed waste on a national level.
3. Development of a plan to collect and analyze mixed waste data and the development of a pretest questionnaire.
4. Administation of the pretest, production of the final questionnaire, and completion of the overall survey design.
5. Collection and analyses of mixed waste data.

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[a]EPA recently published a final decision *not* to list used oil as a hazardous waste in 57 FR 21524, May 20, 1992.

6. Compilation of a national mixed waste profile.
7. Identification of available treatment technologies to meet applicable EPA treatment standards for Land Disposal Restricted (LDR) wastes and, if possible, to eliminate the hazardous component of specific mixed waste streams.
8. Documentation of the study results in an NRC NUREG report.

1.3.1 Evaluation of Available Mixed Waste Information

Available information on the volumes, characteristics, and treatability of mixed waste were compiled and evaluated. This included:

- A literature search to identify and obtain pertinent sources of mixed waste information. Such information included mixed waste survey reports and survey forms prepared by states, compacts, or other parties. Some information was also obtained from studies in progress and from projects that are, as yet, unpublished.
- An evaluation of current and projected mixed waste inventories, the radiological and chemical characteristics of the mixed waste, and the treatability of the various types of mixed waste to meet Resource Conservation and Recovery Act (RCRA) requirements. An effort was made to distinguish between currently available treatment technologies, newly developed technologies, or technologies that may be available in the near future.
- Identification of the assumptions underlying the projections made in past surveys, such as a state's decision to include certain waste (e.g., waste oils) as hazardous waste under RCRA and how these assumptions affected the results of the study.
- An assessment of the potential that mixed waste streams or volumes that were misreported or overlooked, based on the National Profile development team's knowledge of the operations and activities within the commercial nuclear industry. This assessment addressed the potential for significant volumes of mixed waste being unaccounted for because they were reported under a designation that precludes consideration [such as waste reported as an "asset" (e.g., lead to be reused as shielding)].
- An evaluation of previous mixed waste surveys to determine their applicability to the development of a national mixed waste survey. This included contacting individuals who have conducted past surveys.

Based on the available information at the time this study was initiated (late 1990), the projected (1993-1995) national generation rate for mixed waste was estimated to be ~43,000 ft^3 per year. A number of factors were determined to have an impact on the accuracy of the reported

data. These issues included the validity of voluntary surveys, whether waste oils and liquid scintillation fluids were included as mixed waste, the variation in the way individuals filled out the questionnaires, the variation in interpretations of the raw data provided by the surveyed facilities, the variations in time frames for completing the various surveys, the differences in presentation and interpretation of definitions, the different opinions on whether a particular stream is waste or an asset, the uncertainty in when a material becomes a waste, the variations in laws defining mixed waste, and the importance that individual facilities assigned to filling out the survey form accurately.

1.3.2 Evaluation of Adequacy of Existing Information

To determine if the existing data were adequate to estimate and project the volumes, characteristics, and treatability of mixed waste at the national level, the data parameters and an information configuration appropriate for a mixed waste profile were prepared. Existing data were then analyzed individually by compact and/or state to determine their ability to meet these requirements.

This evaluation indicated that the differences in the questions asked, the variation in the definitions and instructions provided, and the attention shown to completing the various questionnaires led to major difficulties in reconciling the data from the various surveys. Thus, it was recommended that a new survey reaching a wide selection of potential mixed waste generators be conducted. Because a great deal of current mixed waste data already existed, although in a wide variety of forms and in varying quality, it was also recommended that the existing data be acquired, where available, summarized, and compared with the results of a new survey.

A national mixed waste generation rate of 51,000 ft^3 per year was estimated as the lower baseline for those compacts/states reporting mixed waste generation. See Sect. 4.3.2, Table 4.18 for more information on this projection.

1.3.3 Data Collection Plan

The object of Task 3 was to develop a detailed plan necessary to collect and analyze the mixed waste data for the compilation of the national mixed waste profile. Included in the plan is a statement of the task's objectives, specification of the survey design, and a description of the mixed waste database that was to be developed. The specific parameters for the data collection plan were developed as follows:

- The national mixed waste volumes were to be determined within a factor of 2 for both 1990 annual mixed waste generation rates and the total quantity of mixed waste in storage at the end of 1990.

- The factor of 2 also applied to mixed waste volumes for each of the major facility categories. The major categories consisted of nuclear utilities, medical, industrial, academic institutions, and NRC-/Agreement State-licensed government facilities.
- The radiological characteristics were to include the Low-Level Radioactive Waste (LLRW) Class (A, B, C, etc.), as defined in 10 CFR 61.55, and a listing of the major nuclides present.
- The hazardous waste characteristics were to include the EPA waste codes (D, F, K, P, or U series) and a common name descriptor.
- Information was to be acquired to determine the relationship between mixed waste stream generation and any plans the facility had for reducing or eliminating that waste stream.
- Information was to be acquired on how the various mixed waste streams are presently being treated, stored, and/or disposed of.

The study design specifications were provided by David C. Cox & Associates and are included as Appendix A. A detailed description of the data collection methods employed and the final mixed waste profile are presented later in this report.

1.3.4 Administration of the Survey Pretest

Twenty facilities belonging to the Appalachian Compact Users of Radioactive Isotopes (ACURI), the association of radioactive licensees within the Appalachian Compact, agreed to cooperate in the initial test phase of the national mixed waste survey. These 20 facilities comprised a broad mix of both large and small facilities within each of the major facility categories. Oak Ridge National Laboratory (ORNL) mailed pretest survey forms to each of the facilities on August 16, 1991, and made follow-up visits to 9 facilities. Other than the strong support that the ACURI, through its executive secretary and its board of directors, extended to the mixed waste profile effort and the individual contacts with each of the facilities, administration of the pretest followed the same methodology used for the actual survey.

Based on the data collected, the comments received during actual site visits to ACURI member facilities, and the various discussions among the mixed waste profile team members, the pretest survey questionnaire was modified to enhance its usefulness. The final survey questionnaire is included as Appendix B.

1.4 Generation of the Mixed Waste Profile

A major component of this project consisted of collecting the mixed waste data necessary to compile a national profile on mixed waste characteristics, volumes, and treatability. Detailed descriptions of the data collection methodology are presented in Sect. 3. A compilation and presentation of the national mixed waste profile including estimation procedures, profile description, major facility category and hazardous stream presentations, and a discussion of the usefulness and limitations to the profile are detailed in Sect. 4.

Another important part of this study was the identification of existing treatment capacity for specific mixed wastes reported in the survey. Various types of treatment technologies are evaluated such as incineration, compaction, solidification, vitrification, including other methods that could meet applicable EPA treatment standards and, if possible, render hazardous wastes nonhazardous. Organizations that currently have the capability to treat mixed waste and those that may have future mixed waste treatment capabilities were also reported as part of the analysis.

2 Review of Relevant Regulations Affecting the Mixed Waste Profile

Low-level radioactive mixed waste is regulated under a dual framework created by Congress. The NRC (or NRC Agreement States) and EPA (or EPA authorized states) independently regulate different components of the same waste. The AEA of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and other statutes provide authority to NRC to regulate the possession and use of special nuclear material (fissile materials), source material (the raw materials of nuclear energy), and byproduct material (fission and activation products and uranium mill tailings and associated processing wastes). NRC has the primary responsibility for regulating nuclear power and nonpower reactors, academic institutions, health care facilities, commercial facilities, and Federal facilities such as Veterans Administration hospitals, the National Institutes of Health, and the National Institute of Standards and Technology that use source, special nuclear, or byproduct material. Section 274 of the AEA allows for the discontinuance of certain regulatory authority by NRC and assumption of this authority by the states. States may assume authority for licensing and regulating byproduct materials, mill tailings, source material, and small quantities (less than 350 g) of special nuclear material. An agreement between the Governor of the State and NRC allows states to assume this authority — hence the term "Agreement State."

EPA regulates the hazardous component of low-level radioactive mixed waste under RCRA. The EPA's authority to regulate the hazardous component of mixed waste was first clarified in

"EPA Clarification of RCRA Applicability to Mixed Waste" (51 FR 24505, July 3, 1986) and was subsequently addressed in "DOE Clarification of the Definition of Byproduct Material" 52 FR 15937, May 1, 1987). The former provided EPA's legal interpretation of the source, special nuclear, and byproduct material exclusion to the definition of solid waste found in RCRA Section 1004(27) and required authorized states to obtain authorization for mixed waste. The latter, referring only to byproduct material, indicated that only the actual radionuclides, not the entire waste stream, are considered to be byproduct material; therefore, EPA retains authority to regulate the hazardous portion of the waste stream under RCRA.

2.1 Regulation of Low-Level Radioactive Waste

Source, special nuclear, and byproduct material are subject to regulation under the AEA. NRC or NRC Agreement States generally administer the AEA for commercial and non-DOE Federal facilities while DOE regulates radioactive materials at DOE facilities. NRC is responsible for licensing and regulating nuclear facilities and materials and for conducting research in support of the licensing and regulatory process. Activities must be conducted in accordance with the National Environmental Policy Act (NEPA) of 1969, as amended. NRC responsibilities include protecting the public health and safety, protecting the environment, and safeguarding nuclear materials in the interest of national security. Agency functions are performed through: (1) standards setting and rulemaking; (2) technical reviews and studies; (3) conduct of public hearings; (4) issuance of licenses; (5) inspection, investigation, and enforcement; and (6) research (see "Regulating the Disposal of Low-Level Radioactive Waste, A Guide to the Nuclear Regulatory Commission's 10 CFR Part 61").

Some radioactive materials such as naturally occurring or accelerator-produced radioactive material (NARM) are not subject to regulation under the AEA and, therefore, are not subject to regulation by NRC. However, NRC does have authority for limited types of NARM, including source material (uranium and thorium) and uranium and thorium mill tailings and associated wastes. NARM waste is currently not identified as hazardous under RCRA; however, it could be because it was not specifically excluded from regulation under RCRA as were other radioactive materials. NARM regulation is primarily a state responsibility, at present, if the State chooses to exercise it.

Low-level radioactive waste is defined in the LLRWPAA to mean radioactive material subject to NRC regulation that is not high-level waste, spent nuclear fuel, or byproduct mill tailings and waste, which NRC classifies as low-level radioactive waste. The NRC radioactive waste classification methodology (10 CFR Part 61) is a systems approach to control the potential

dose to people from the disposed waste. The components of the system include the site characteristics, the design and operation of the site, the institutional controls, the waste form, and intruder barriers. The quantity and type of radionuclides permitted for disposal in each class are based on combinations of these various components and on concentrations of radioactive materials that are expected to be in the wastes and that are important for disposal. Three classes are established for routine near-surface disposal: Class A, Class B, and Class C.

Low-level radioactive waste contains short-lived and long-lived radionuclides. Three important time intervals are relied on in setting the waste classification limits. One is the length of time the government will actively control access to the site (100 years). The second is the minimum stability of the waste form (300 years). The third is the expected lifetime of engineered barriers or assured burial depth (for intruder protection) and the time when total failure of the waste form is assumed to occur (500 years). Concentrations of short-lived radionuclides permitted in the waste are higher than concentrations of long-lived radionuclides, because the short-lived nuclides will significantly decay during the 100 years of assumed institutional controls. Shorter-lived nuclides will also significantly decay during the 300-year design lifetime of stabilized wastes. The limits are further set so that at the end of the 100-year institutional control period, no active site controls or maintenance are needed, and so that at the end of 500 years, no reliance on engineered features or waste form are needed for intruder protection. The limits specified for both short- and long-lived radionuclides ensure that the performance objectives will be met. Details of the concentration limits that define waste form classification as either A, B, or C are contained in 10 CFR 61.55.

Any class of radioactive waste that contains a hazardous waste as defined in RCRA is considered mixed waste. The radioactive component of commercial mixed waste is generally low-level radioactive waste and is the only area of concern for this study.

2.2 Regulation of Hazardous Waste

RCRA and HSWA set the regulatory framework for hazardous waste. Subtitle C of RCRA established the regulation of hazardous waste from generation through its ultimate disposal ("cradle-to-grave"). RCRA defines solid waste as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities". Solid waste, however, does not include "source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954..." [RCRA Section 1004(27)]. As indicated above, EPA, NRC, and DOE

interpret the exception for source, special nuclear, or byproduct material as referring only to the radioactive component of the waste, and not to the entire waste mixture. Thus, AEA regulations apply only to the radioactive components and, if the waste contains RCRA hazardous waste components, the waste also becomes subject to regulation under RCRA.

HSWA amended RCRA significantly. A key element of HSWA is the LDR program which restricts the land disposal of hazardous wastes, including mixed wastes, unless a waste meets EPA treatment standards or a "no-migration" determination has been made for a specific site. The LDRs initially applied to waste listed or identified as of November 8, 1984, under RCRA. They now also cover several hazardous wastes listed after November 8, 1984, for which treatment standards have been developed. Treatment standards exist for hazardous waste that contains solvents (F001 to F005) dioxins (F020 to F023 and F026 to F028) and California list wastes (halogenated wastes, certain metal-bearing wastes, polychlorinated biphenyls, cyanide, and corrosive wastes). EPA deferred issuing treatment standards for most radioactive waste mixed with scheduled hazardous waste (i.e., all wastes listed as of November 8, 1984, which are described in the First, Second, and Third Third rules; 53 FR 31137, August 17, 1988; 54 FR 26594, June 23, 1989; and 55 FR 22520, June 1, 1990) and that are not solvents or dioxins, or California list waste until the promulgation of the last scheduled LDR rule on May 8, 1990 (the Third Third rule). After May 8, 1990, all mixed wastes falling into the above categories of waste were restricted from land disposal. However, for all mixed waste described in the First, Second, and Third Third rule, EPA granted a two-year national capacity variance based on the lack of treatability capacity. This variance (which expired on May 8, 1992) delayed the imposition of the LDR treatment requirements for land disposal of mixed waste until the expiration date. Storage of these restricted wastes is also prohibited after May 8, 1992 (with a very few exceptions) unless storage is for the sole purpose of accumulating sufficient quantities in a tank or container to facilitate proper recovery, treatment, or disposal of the waste (see 40 CFR 268.50, the storage prohibition). Under the LDR, the RCRA-regulated hazardous portion of mixed waste must meet the appropriate treatment standards for all applicable waste codes before land disposal (in the absence of a "no-migration" determination). Mixed waste for which adequate treatment capacity is not available must be stored in accordance with all RCRA storage requirements until treatment capacity becomes available (although such storage may constitute a violation of the LDR storage prohibition) or a site-specific variance from the treatment standard (40 CFR 268.44) is granted. Currently, a capacity variance is in effect for mixed waste that contains certain newly listed wastes (57 FR 37194, August 18, 1992) and debris and soil contaminated with mixed waste (57 FR 47772, October 20, 1992).

2.3 State Regulations

RCRA allows for the delegation of authority of the Federal regulatory program to the states. The AEA allows for the discontinuance of certain regulatory authority by NRC and assumption of this authority by the states. NRC-granted Agreement State status and EPA-authorized RCRA state programs implement the regulatory programs. In certain cases, state regulations may include provisions more stringent than the applicable Federal regulations.

2.3.1 Low-Level Radioactive Waste in Agreement States

Twenty-nine states have signed agreements with NRC (under Subsection 274b of the AEA), enabling the various "Agreement" States to regulate the use of source, special nuclear (limited quantities), and byproduct material within their boundaries. This applies to all radioactive material except that from nuclear utilities and fuel cycle facilities (regulated by NRC) and DOE facilities (regulated by DOE). Each "Agreement" provides that the state will use its best efforts to maintain continuing compatibility with the NRC's regulatory programs. States that plan to license new disposal sites must adopt most of the provisions of 10 CFR Part 61 to maintain compatibility. All Agreement States must adopt the manifest system in 10 CFR Part 20 to cover waste generators in the state. NRC maintains a continuing relationship with each Agreement State to ensure continued compatibility; however, states are independent regulatory authorities under the agreement. In making licensing decisions, states may take local conditions such as weather or public opinion into account as long as the program remains compatible and adequate to protect the public health and safety.

2.3.2 Hazardous Wastes in Authorized States

The Federal RCRA program was developed to be implemented primarily by the states, with EPA oversight. A state must develop a program that is equivalent to, no less stringent than, and consistent with the Federal program. State programs may be more stringent than their Federal counterpart. Once authorized, the state has primary responsibility for implementation and enforcement of RCRA requirements within its boundaries. Authorized state programs operate in lieu of the Federal RCRA program, although EPA retains oversight and residual enforcement authority. EPA administers the Federal RCRA program in unauthorized states. In addition, EPA administers HSWA requirements (e.g., LDRs) in all states until they are authorized for these provisions.

A state authorized for the RCRA program may choose to define additional wastes as hazardous under its state hazardous waste program. Maryland, for example, even includes radioactive materials on its hazardous waste lists.

2.3.3 Authorization for Mixed Waste

EPA has formally clarified its position that the hazardous component of mixed waste is subject to RCRA regulation (see 51 FR 24504, July 3, 1986). In the notice, EPA called for authorized states to revise their authorized programs and incorporate the authority to regulate the hazardous components of mixed waste. States authorized for the base program (pre-HSWA) were allowed a maximum of 2 years from the promulgation of the notice to incorporate the mixed waste authority (i.e., until July 3, 1988). The July 1988 deadline was extended one year. As of September 30, 1992, authorization for mixed waste authority has been given to 31 states and 1 territory (Guam). In those states that are authorized for RCRA's base program but which have not received mixed waste authority, mixed waste is not subject to RCRA hazardous waste regulations, including the land disposal restrictions until the state is authorized for mixed waste.

At present there are 15 states (Alabama, Arizona, Delaware, Maine, Maryland, Massachusetts, Missouri, Montana, New Hampshire, New Jersey, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia) authorized for base RCRA but not authorized for mixed waste. According to a recent EPA guidance document Federal restrictions for mixed waste disposal are not applicable in these states. In fact, mixed waste may not even be defined or regulated as hazardous waste in these states. However, it does appear that facilities in most of those states in this category treat mixed waste as if it was regulated under RCRA. In those states that are not authorized for RCRA's base program and in states authorized for mixed wastes, the RCRA land disposal restrictions are in effect.[b]

3 Collection of Mixed Waste Data

3.1 Objective

The primary objective of the joint NRC- and EPA-sponsored project under Tasks 5 and 6 was to collect and analyze the data reported on the survey questionnaire (see Appendix B). The data collected supported the development of the national mixed waste profile.

[b]"Guidance on the Land Disposal Restriction's Effects on Storage and Disposal of Commercial Mixed Waste," Office of Solid Waste and Emergency Response (OSWER) Directive No. 9555.00-01, September 1990.

3.2 Collection Methods

A preliminary letter (drafted and cosigned by NRC and EPA and included in Appendix B) was mailed to all the compacts and their member states, to each of the unaligned states, and also to all NRC licensees. The letter informed them of the purpose of the survey and requested their aid in helping to ensure that the compilation of the national survey would be a meaningful and credible undertaking. In addition, a number of industry groups volunteered to support and disseminate information on the survey.

Based on the study design specifications detailed in Appendix A, 1,323 facilities were randomly selected, from among 2,936 facilities with a high potential to generate mixed waste, to receive mixed waste surveys. These facilities were sent the mixed waste questionnaire in early November 1991. A formal survey monitoring procedure was established that included a survey questionnaire return tracking system and a system that allowed for follow-up call documentation.

By the end of December 1991, only 190 surveys had been returned. At that time, a series of phone calls began, by trained data collection specialists, to those facilities that had not yet returned their surveys. These calls were implemented to encourage the facilities to participate in the survey, to offer any assistance required to fill out the survey or, if necessary, to acquire any survey information over the telephone. Generally, the latter approach was used only for those facilities that indicated they generated little or no mixed waste. Initial procedures called for five telephone attempts to contact a cognizant person responsible for completing the questionnaire. In a number of cases, additional telephone contacts were attempted before a data collection specialist discontinued his or her effort to obtain a survey response from a specific facility.

By the end of April 1992, ORNL had received 995 questionnaires. An additional 21 facilities were determined to no longer be in business. Survey respondents and those facilities that were no longer in business accounted for the approximately 77% return-resolution rate (completed surveys/questionnaires sent out).

3.3 Data Collection

As questionnaires were received at ORNL, they were noted on the master list of surveyed facilities. All data were initially checked by a principal investigator for obvious errors and inconsistencies, misinterpretation of instructions, incomplete data, and clarifications. In general, all data from the survey questionnaires were included in the database. A number of exceptions to this procedure occurred when facilities inadvertently left out a waste code, description, or stream number. Obvious errors were corrected where appropriate. Responses that required clarification were followed up with a telephone call to the responding facilities. Minor inconsistences and/or

gaps in information were not usually corrected due to the large number of questionnaires that were returned to ORNL.

One major exception to the above procedure occurred during the survey. One facility reported that it generated three waste streams with a total of over 2,000,000 ft^3 of liquid mixed waste generated in 1990. Checking with this facility confirmed that these entries were valid. However, it was decided not to include these three waste streams in the database because (1) they appeared to be generated from a one-time event which is not likely to be repeated; (2) the facility has petitioned the state to have the streams delisted and, if successful, they would no longer be considered mixed waste; and (3) inclusion of these streams would invalidate the statistical interpretation of the mixed waste database and prevent its usefulness as a predictive tool for the nation as a whole. This response, however, indicates a large potential variability in the generation rate of mixed waste by specific facilities.

3.4 Data Processing

An initial data cleaning process identified and categorized the major mixed waste streams [e.g., liquid scintillation fluids (LSFs), oil, lead, etc.). Any unclassified waste streams were entered into an "unassigned" category until further classification. Daily activity reports were printed and proofread. Trend analysis was also employed as a data integrity check after the data were entered into the database. This entailed the listing of records that did not fit the norm for selected criteria. The abnormal records were then compared with the data in the original questionnaires and either confirmed or corrected. Variations of reports, using a variety of category breakouts, were made and compared to ensure congruity in the totals. "Smart" algorithms were used to seek out orphaned data records that did not match valid facility or stream identification numbers. This aided in the double-checking for data entry errors. Original questionnaires were retained for future reference.

3.5 Database Description

An analysis of the questionnaire indicated that several relational data files were necessary to include all of the available data while maintaining data integrity. The personal computer-based commercial software, FoxPro, was selected as the database program because of its versatility. The data from each questionnaire were organized into nine subfiles based on the format of the questionnaire and linked together through the use of an identification code (IDNUMBER) unique for each queried facility. This organizational structure provides for the separation of exact and

range data and enables the data to be used independently in summations and statistical calculations. Comment fields were included throughout the database for additional information that may be needed to clarify the data. The database contains the responses from 1,016 facilities that use a total file length of about 15 MB. Specific descriptions and contents of the data subfiles and definitions of the fields within the subfiles are given in Appendix C.

3.6 Data Tabulation

The reports generated were tabulated using several classification schemes. The main tabulation was based on how the facility identified itself. Other classifications used the "GROUPID" field (LSF, oil, organic, etc.) to subdivide the waste streams in the tabulations. An "Other" category was added to the Waste Stream classification to account for two types of wastes—those containing multiple types or mixtures of hazardous wastes and unique waste streams such as lead contained in a "freon" mixture. Table D.11, Appendix D, lists all the "Other" mixed wastes that were reported as being generated in 1990. Classification by compact (group of states) was also done, with the nonaligned states tallied individually.

3.7 Disposition of Original Data

Mixed Waste Survey participants were ensured of the greatest confidentiality possible. The joint letter from the sponsors (see Appendix B), NRC and EPA, indicated the data were not being collected for any enforcement purposes. ORNL was directed NOT to provide the identities of any of the survey respondents to NRC or EPA "unless a future development involving the protection of the public health and safety and the environment," warrants it. "Except as outlined above, data and results from the survey will only be provided to NRC, EPA or other groups or individuals, as approved in writing by the NRC Office of Nuclear Material Safety and Safeguards (NMSS) Project Manager, in an aggregated format, stripped of any specific licensee identifiers." "At the conclusion of this project, ORNL will retain all raw data that contains facility identification information (e.g., completed survey forms, follow-up call notes and records, records of interviews with specific facilities, etc.) regardless of the form of the record (e.g. hard copy, computer disk, etc.) for 7 years. Seven years after completion of this project, ORNL will destroy this information."

4 National Mixed Waste Profile

4.1 Estimation Procedures

4.1.1 Survey Design Objectives

The objective of this project was to compile a profile of national commercial mixed waste volumes to within a factor of 2 (with 95% confidence limits) for both 1990 annual mixed waste generation rates and, if possible, the total quantity of mixed waste in storage at the end of 1990. This factor of 2 also applied to mixed waste generation rates for each of the major facility categories. The categories include nuclear utilities, medical, academic, industrial facilities, and NRC/Agreement State-licensed government facilities. Based on these objectives and the necessity of limiting the survey of facilities to a manageable level, limitations were placed on the numbers and characteristics of those facilities chosen to receive the survey questionnaire.

4.1.2 Selecting the Frame

Those facilities that were deemed suitable for investigation in this study were facilities having the potential to generate low-level mixed waste. Four different strata were used to identify these facilities and are defined as follows:

- ORNL List. This stratum is a list of 444 facilities which was compiled by ORNL. It includes all nuclear utilities and other facilities which have been designated by ORNL as likely generators of mixed waste. Possible reasons for the inclusion of particular facilities in this stratum were their appearance on a list in a governor's certification (pursuant to the LLRWPAA of 1985 as amended, certification by the governor of the intent of the state to safely manage LLRW generated within its borders) or on a compact/state survey as having generated, or having the potential to generate, mixed waste.
- Shipper's List. This stratum contains all 1990 shippers of LLRW (to any of the three commercial burial grounds) who do not already appear on the ORNL list.
- NRC Potential Mixed Waste Generators with EPA Permits. This list includes those facilities having NRC licenses and Material License Program Codes which have a high potential for generating mixed waste and have an EPA Permit to treat, store, or dispose of hazardous waste, or have an EPA identification number. The codes defined as having high potential for mixed waste generation are shown in Table 1, Appendix A.
- NRC Potential Mixed Waste Generators without EPA Permits. Same as above but without an EPA permit.

The likelihood that any given facility generates mixed waste depends on the actual processes and materials in use at the facility. After duplicate names were removed from the lists described above, approximately 2,936 facilities were finally estimated to be in the 4 strata. These are defined as the overall universe or entire population of interest.

Two groups of potential mixed waste generators were not included in the survey target population. The first are those that have NRC licenses and Material License Codes which were determined not to have a high potential for generating mixed waste because of the nature of the licensed activity, such as private doctor's offices. The second are those facilities in NRC Agreement States and not on the ORNL list or the shipper's list. The first group was not included in the survey target population because of a low potential for generating mixed waste and its size (over 6,000 facilities). The second group was not included because of a low potential for mixed waste generation, the lack of facility names and addresses, and for its large size (~16,000). The size of a group was, however, a secondary factor in both of these exclusions.

4.1.3 Selecting the Sample

Based on the objectives of the study as outlined previously, a sample size determination was made using the number of facilities in each of the population substrata, estimates for the means and variances of the total volume of mixed waste within each of the substrata, and the accuracy requirements of the survey. Estimates for the means and variances were based on several compact surveys completed prior to this study. The actual detailed discussion of the final sample size for each substratum is discussed in Appendix A.

Potential generators of commercial mixed waste were grouped into 17 substrata (groups), as shown in Exhibit 5 of Appendix A, based on the type of facility (nuclear utility, medical, academic, industrial facilities, or NRC/Agreement State-licensed government facilities) and whether they were on the ORNL List, the Shipper's List (excluding those on the ORNL List), or NRC licensees either with or without EPA permits. From each substratum and independently of the other strata, a simple random sample of facilities was selected. For nine of the substrata, all facilities within the substrata were selected for the sample.

As indicated in Table E.6 of Appendix E, the overall sample size was $n_{..} = 1,323$ facilities selected from an estimated overall universe of approximate size $N_{..} = 2,936$ facilities. Details on the precision requirements for determination of sample size are given in Appendixes A and E.

4.1.4 Weighting of Sample Data and Estimation of Total Volumes

Each respondent facility was assigned to only 1 of the 17 substrata as indicated in Sect. 4.1.3. The sampling weight for an individual respondent depended on the substratum in which it was originally assigned. This weighting factor was computed by dividing the estimated number of

facilities in its assigned substratum by the number of sample respondents, including the number of sample facilities that reported that they were out of business. For example, of 165 academic facilities on the Shipper's List and not on the ORNL List, 111 survey responses were received, and no facilities were found to be "out of business." Thus, the sample weight for this substratum is computed to be 165/111 = 1.4865. The other sampling weights used are given in Table E.7 of Appendix E and range from a low of 1.026 to a high of 31.5. In other words, these numbers indicate that each response from these facilities represent anywhere from 1.03 to 31.5 other facilities in the same substratum.

The estimate of a total volume, $\hat{T}_D$, of a particular waste for any specific collection of facilities, D, in the entire universe was computed as follows. First, each sample respondent included in the specific collection of facilities (D) was identified. The reported waste volume for each sample respondent belonging to collection D was then multiplied by the appropriate sampling weight. The sum of all such products for sample respondents from D gave the estimated total volume, $\hat{T}_D$. The collection of samples, D, can be any collection desired such as all industrial, medical in state "X", etc. More details on estimation and the computation of selected standard errors (s.e.) are given in Appendix E.

4.1.5 Expected Accuracy and Precision of Survey Results

As discussed in Sect. 3.3 of Appendix A, the sample sizes for each of the 17 substrata were determined with the goal of achieving a relative standard error (r.s.e.) of 10% for the national estimate of the total volume of waste generated. While the final sample sizes selected greatly exceeded sample sizes necessary to provide estimates within the desired accuracy factor of 2 (as described in Appendix A), the selected sample sizes provide a significant factor of conservatism in the survey design and allow for nonsampling error. This nonsampling error reflects how accurately the completed questionnaire represents reality and is not related to the statistics involved in choosing the sample size or to the number returning the questionnaire. The estimated r.s.e., for sampling error only, that were realized are given below:

Category	Estimated relative standard error	
Academic	10.5%	(=3,055/28,982)
Government	22.6%	(=5,978/26,500)
Industrial	22.6%	(=11,414/50,430)
Medical	14.7%	(=2,928/19,904)
Nuclear utilities	5.2%	(=703/13,625)
National	9.7%	(=13,579/139,441)

Note that each estimated r.s.e. given above is obtained from Table 4.3 by dividing the estimated s.e. by the estimated total volume generated. Four of the five r.s.e. exceeded the desired goal of 10% (only a goal used in estimating sample size); however, the r.s.e. for the estimated total commercial mixed waste generated in the country (9.7%) is almost equal to the desired goal. [Computed as the square root of the sum of the individual group variances (the square of the indicated s.e.) divided by the estimated total volume of mixed waste generated.] Based on the conservative sampling design of the survey as discussed above, the final results obtained at the national level are well within desired accuracy of a factor of 2 for both sampling and nonsampling errors.

4.1.6 Approximate 95% Confidence Intervals

Using the notation of Sect. 4.1.4, s.e. $\hat{T}_D$ is the estimated s.e. of the estimator $\hat{T}_D$. Assuming that the estimator $\hat{T}_D$ has a normal distribution, an approximate 95% confidence interval for $\hat{T}_D$ is given by:

$$\hat{T}_D \pm 1.96\,[\text{s.e.}(\hat{T}_D)]\,.$$

Approximate 95% confidence intervals for the total volume generated in the United States and for the total generated waste for each major category are given below:

Category	Approximate 95% confidence interval
Academic	22,994 — 34,970
Government	14,775 — 38,209
Industrial	28,059 — 72,801
Medical	14,165 — 25,643
Nuclear utilities	12,247 — 15,003
National	112,818 — 166,048

From the above data, one may conclude that "we are approximately 95% confident that the actual total national volume of commercial mixed waste generated in 1990 is between 113,000 ft^3 and 166,000 ft^3." Similarly, it can be said that "we are approximately 95% confident that the actual total volume of commercial mixed waste generated in 1990 by academic facilities is between 23,000 ft^3 and 35,000 ft^3."

4.1.7 Limitations of Survey Design

As discussed in Appendix A, the sampling plan (including sample sizes) was designed to provide conservative estimates of the total volumes of mixed waste at the national level for each of the five facility categories. Reliability of the estimates at these levels are reflected in Table 4.3 and Sects. 4.1.5 and 4.1.6.

Estimates of mixed waste volumes calculated at the compact/state level are far less reliable, mainly due to fewer samples in these substrata. For this reason, estimates of mixed waste volumes and generation rates for individual states and compacts should be used with great caution.

4.2 Description of the National Commercial Mixed Waste Profile

The National Profile on Commercial Mixed Waste is a statistically based estimation of the 1990 generation rates and volumes of commercially generated mixed waste. The amounts of mixed waste generated in 1990 and in storage as of December 31, 1990, for the National Profile was estimated by examining the responses to 1,323 questionnaires (see Appendix B) which were sent to a broad spectrum of potential generators of mixed waste on November 1, 1991. The responses of 1,016 facilities (77% response rate) were entered into a 1,016 by 15 KB (a total of 15 MB) database from which the National Profile was estimated employing weighting factors described in Sect. 4.1.4.

4.2.1 Facility Categorization

Five broad categories of generators of mixed waste were established which included academic, industrial, medical, NRC/state-licensed government facilities, and nuclear utilities. These were then subdivided by size, functionality, type of business and, if applicable, type of reactor. Illustrated in Table 4.2 are the five generalized categories as they were subdivided showing the number of questionnaire responses received in each subcategory.

In addition to categorization, the questionnaire asked the respondents to indicate their EPA facility classification, if possible. A total of 616 responses were obtained to this query. Large quantity generator status (>1,000 kg/month) was indicated by 216 facilities and small quantity generator status (100 to 1,000 kg/month) was designated by 186 facilities. Also, 82 facilities reported that they were conditionally exempt small quantity generators (<100 kg/month), and 132 facilities indicated they had no EPA classification.

4.2.2 Low-Level Radioactive Waste (LLRW) Stream Descriptions

Section B of the questionnaire (see Appendix B) requested information on the amount of class A, B, or C LLRW shipped either to a broker or directly to one of the three burial sites

(Hanford, WA; Beatty, NV; Barnwell, SC). The amount of LLRW reported by the respondents is discussed in Sect. 4.3. Also requested were data on LLRW stream number, a coded number indicating the type of LLRW from a listing of 26 different potential waste streams shown in Attachment 1 of the questionnaire (Appendix B, p. 1-1 and 1-2) and a waste stream name together with the generating practice yielding the waste stream. The same information was also requested on stored waste. The responses to the LLRW stream number and name request were not provided by all facilities. Some respondents reported in detail on this information while others often neglected it entirely or were very cursory in their responses.

4.2.3 Estimated Mixed Waste Generation Rates by Facility Category

The results of the National Profile are presented in Table 4.3. Column 1 of Table 4.3 details the total mixed waste generated during 1990 by facility category as reported by the 1,016 respondents to the survey questionnaire. Note that the generation volumes **reported** by the academic, industrial, and NRC/Agreement State-licensed government categories were approximately equivalent and equaled 71% of the generated mixed waste reported for 1990. However, the weighted data in column 2, representing the **estimated** national generation rate for each category, indicate a somewhat different picture. The previous three categories are projected to have generated nearly 76% (106,000 ft^3) of the total mixed waste; however, the industrial category is projected to have produced more than 36% (50,000 ft^3) of the total 140,000 ft^3 in the United States in 1990. The large differences between "as reported" data and projected generation rate are due to the large number of facilities in the survey frame in the industrial category coupled with a relatively small sample size within critical groups (see Sect. 4.1.4 for a discussion on weighting factors). It is interesting to note in Table 4.3 that the estimated total generation of mixed wastes by nuclear utilities is <10% (~14,000 ft^3) of the total commercial mixed wastes generated in the United States.

4.2.4 Stored Mixed Wastes by Category

Amounts of mixed waste stored as of December 31, 1990, listed by category, are depicted in Table 4.4. Facilities returning the questionnaire reported 44,000 ft^3 in storage as of December 31, 1990. Applying the weighting factors developed in Tasks 5 and 6 yields a national volume of 75,000 ft^3.

On an "as reported" basis, nuclear utilities have the largest amount of mixed waste in storage. However, the estimated amount in storage for the industrial category, after application of weighting factors, is nearly twice the amount estimated for nuclear utilities. This is because the weighting factors for the latter category are very close to 1 since all of these facilities were contacted and the response rate was over 97% (76 of 78). Not all of the stored mixed waste

reported was untreatable. In fact, some of it was awaiting accumulation of sufficient quantities before being shipped to off-site treatment facilities (e.g., liquid scintillation wastes). **It should be noted that treatment and storage data in Tables 4.11 through 4.16 are not necessarily horizontially additive since waste in either category may have been generated prior to 1990.**

4.2.5 Mixed Waste That Currently Cannot Be Treated

Mixed waste that currently cannot be treated represents waste that may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity. Two categories, NRC/Agreement State-licensed government and nuclear utilities appear to have the largest amount of untreatable waste [69% of the reported and 59% of the projected total (about 4,800 ft^3) of these wastes] as shown in Table 4.5. Chlorinated fluorocarbons (CFC), reported by nuclear utilities, account for over 23% (866 ft^3) of the "reported" mixed waste designated as untreatable with present technology and about 18% (889 ft^3) of the estimated wastes requiring ultimate disposal. The generation of these wastes should be decreasing rapidly as substitute materials are used and laundries serving nuclear utilities rapidly shift to aqueous-based clothes washing facilities. Not all respondents to the mixed waste questionnaire reported on their treatment options, and some of their untreatable waste may have gone directly into storage. Therefore, the estimate of 4,838 ft^3 reported in Table 4.5 may be an underestimate of the total amount of untreatable mixed waste generated in 1990.

Upper and lower bounds can be set on the volume of mixed waste that currently is untreatable. Assuming that LSF, oils, organics (not halogenated), and corrosive wastes are treatable under currently available technologies and deducting them from the estimated national total mixed waste generation rate leaves ~18,500 ft^3 of untreatable mixed waste. Thus, with this as an upper bound and the ~5,000 ft^3 mentioned above as a lower bound, the untreatable mixed wastes range from 3.5 to 13.3% of the estimated 1990 national generation rate of about 139,000 ft^3. Please note, however, that the capacity to treat <u>all</u> so-called "treatable" mixed waste in this report may not be available.

4.2.6 Types of Mixed Wastes Reported

In excess of 62% of the mixed wastes reported as generated during 1990 consisted of LSF wastes. After application of the statistical weighting factors (see Sect. 4.1.4), the scintillation fluid wastes were estimated at nearly 72% of the total projected generation of commercial mixed wastes in the United States. In contrast, the estimated generation rates for waste streams such as mercury-containing or cadmium-containing streams are very small as indicated in Table 4.6. Illustrated in Fig. 4.1 is a summary of the various types of waste streams reported as generated by

the five major facility categories. In addition, a mixed waste stream of appreciable size, not shown in Fig. 4.1, is a stream labeled as "Other" in Table 4.6. This waste stream, representing 7.5% of the projected mixed waste generation, has multiple hazardous components and cannot be delineated as a single waste stream. A detailed breakout of the contents of this "Other" category is contained in Table D.11 of Appendix D.

Table 4.7 is a detailed breakdown of the amounts of the various types of mixed waste in storage as of December 31, 1990. (This is the same breakdown of waste types as shown in Table 4.6.) It depicts significant quantities of cadmium-containing wastes (35% of projected waste in storage) being stored by industrial facilities and CFC-containing wastes being stored by the nuclear utilities (11% of projected waste in storage).

Table 4.8 details the amounts, by waste-stream type, of mixed wastes designated as untreatable by currently available technologies. The two major waste streams in this category are used scintillation fluids and the "Other" types of mixed wastes (21.6% and 22.9%, respectively). The scintillation fluids reported here are considered untreatable because they contain isotopes that cannot be burned either on- or off-site due to license restrictions on the available combustion units.

4.2.7 Estimated Mixed Waste Generated by Compacts and Unaligned States

In order to implement the Low-Level Radioactive Waste Policy Act of 1980, 43 states organized themselves into nine compacts primarily to consolidate their disposal efforts for LLRW. These nine compacts and their member states are listed in Table 4.9. The remaining seven states, the District of Columbia, and Puerto Rico are not aligned with other states and are, essentially, "on their own" to responsibly dispose of LLRW and mixed waste. Listed in Table 4.10 are the categorized estimated generation rates for mixed waste tabulated by compact and unaligned state (including the District of Columbia and Puerto Rico). In interpreting the data shown in this table, please review Sects. 4.1.6 and 4.1.7 regarding the statistical validity and cautions in interpreting these survey data. To aid the reader in assessing Table 4.10, the number of respondents from each compact and unaligned state is also shown. Of interest is the fact that the Appalachian Compact appears to be the largest generator of mixed waste among all the compacts and unaligned states.

4.2.8 Detailed Profile Description by Individual Category

Depicted in Tables 4.11 through 4.15 are detailed listings of estimated waste generation rates by waste type, treatment (on-site, off-site), amount destined for ultimate disposal, and amount in storage for each of the five categories. Depicted in Table 4.16 are similar data for the entire survey (not broken down into categories).

4.3 Profile Validation

4.3.1 Comparison with Manifest Data on Low-Level Radioactive Waste (LLRW)

Very accurate data exist on the shipments of LLRW to the three burial sites in the states of Washington, Nevada, and South Carolina and are based on actual manifests of shipments received at these sites. Comparisons of the LLRW shipped by the various facilities (responses to B-1 in the Questionnaire, Appendix B) with the manifested waste received at the three burial grounds provide a measure of validation concerning the completeness of the survey. The Integrated Data Base (IDB) Program at ORNL, an official DOE database on national radioactive waste, publishes annual data on shipments of LLRW to the three burial grounds. Illustrated in column one of Table 4.17 are the total 1990 LLRW shipments to the three burial grounds listed by compact (nine) and unaligned states (eight and the District of Columbia). Listed in column two of this table are the total volumes of LLRW reported as shipped off site in 1990 by the respondents to the National Profile questionnaire by compact and unaligned state. Generally, many of these shipments from individual facilities will pass through a broker who will treat, combine, or otherwise compact individual packages prior to shipment to a burial ground. Therefore, one might expect the raw totals at the originating point (as shown in column two of Table 4.17) to be somewhat higher than those listed from the manifests at the three burial sites. As indicated in the table, the total LLRW as reported by the respondents is only 1.3% less than that determined from records at the three burial sites for the IDB report. Applying the statistical weighting factors, based on number in the frame and the number of responses in the various categories, yields the projected total shipments of LLRW on a national basis. This total is ~38% greater than that reported in the IDB annual report. You will note in comparing numbers for individual compacts, that in some instances the weighted numbers for LLRW are in reasonable agreement with those listed in the IDB report (e.g., for the Southwestern and Southeast Compacts). In other instances, for example the Appalachian and Midwest Compacts, the weighted data are much higher than listed in the IDB report. **Such differences may illustrate the fact that because this survey was designed as a national survey caution must be employed in interpreting the data in ways other than those for which the survey was designed.** However, the comparison of actual and estimated low-level radioactive waste, from Table 4.17, indicates that the responses to this survey represent a fairly complete sampling of potential mixed waste generators across the United States.

4.3.2 Comparison with Existing Data on Mixed Waste Generation

Illustrated in Table 4.18 is a summary of existing mixed waste generation data gleaned from various 1990-1991 sources including Governor's Certifications compact/state low-level waste surveys and compact/state mixed waste surveys. These data are compared to unweighted and

weighted generation data as determined from the ORNL survey for the National Profile of Mixed Waste. These older data, in general, represent conditions existing during 1989. However, because of their inconsistencies, it was decided that a new national survey, having a defensible statistical basis, should be performed. The most complete data on mixed waste generation found prior to undertaking the National Survey were from the Southwest Compact; reasonable agreement is found between the 1990 projected generation rate of 16,515 ft^3 and the 1989 rate of 21,156 ft^3 as determined by a survey of potential mixed waste generators in that compact. Good agreement is also noted for the unaligned state of New York. However, with the exceptions of the Southwest Compact and the two unaligned states of New York and Texas, the current survey data show much higher generation rates for mixed waste than was indicated by the existing data for 1989. This may be due to inconsistencies found between previous surveys in locating and questioning of potential mixed waste generators. In addition, previous mixed waste surveys were primarily focused on the generation and shipment of LLRW rather than on mixed waste management.

5 The Treatability of Mixed Waste

The objective of Task 7 was the identification of existing treatment capability for specific mixed waste streams identified in Sect. 4.2 and Appendix D. Various types of treatment technologies such as incineration, compaction, solidification, vitrification, or other methods that could meet EPA treatment standards and, if possible, to render hazardous wastes nonhazardous were evaluated. Organizations that currently have the capability to treat low-level radioactive mixed waste, as well as the services these organizations can provide for the treatment of mixed waste, are also identified. For the purposes of the National Profile, an organization is considered to have a treatment capability for mixed waste if that organization has a process that:

1. has been technically demonstrated;
2. has the necessary permits or approvals; and
3. has sufficient approved operating capacity so as to enable a generator to anticipate treatment of his/her waste in a reasonable time frame.

Waste streams, generated nationwide as identified in Sections 4.2 and Appendix D, along with best demonstrated available technologies (BDAT) for their treatment, were examined. This section matches these treatment technologies with each waste stream and also describes treatment services available nationwide for low-level radioactive mixed wastes. A comparison is made of the

availability of treatment services with the demands indicated by mixed waste generation rates and inventories based on the national profile.

5.1 Source of Information

The categories, characteristics, and amounts of mixed waste used in Sect. 5 are based on waste volumes outlined in Sect. 4.2 and Appendix D. Volume distributions by waste category are derived from the database of information provided by a collection of 1,016 completed surveys to the questionnaire (see Appendix B). Further details about the database are contained in Appendix C.

5.2 Characteristics of Mixed Waste

Commercial low-level radioactive mixed waste in the United States consists of a variety of waste streams from a range of sources. Generators of mixed waste include facilities in the government, academic, and industrial sectors, as well as nuclear utilities and medical facilities. Mixed waste generation in the United States for 1990 is estimated at about 140,000 ft^3 (see Sect. 4.2). The mixed waste generated in 1990 covered a broad spectrum of waste types. Table 5.1. shows these categories, along with the volumes generated, amounts stored, primary hazardous constituents, prevalent isotopes, and sources for mixed waste generated in the U.S. in 1990. The distributions of volume and storage by waste category are depicted in Figures 4.3 and 4.5, respectively. The waste types observed are consistent with mixed waste streams identified in other studies.[1-3]

The LSF category is by far the largest mixed waste generation category, comprising nearly 72% of the total estimated volume. Although the largest, in terms of generated volume, the LSF category does not, in general, currently pose a significant treatability problem, nor is it expected to in the future because of the adequate amount of commercial treatment capacity that currently exists and the increasing use of substitute materials. The largest volumes of waste in storage as of December 31, 1990, are cadmium and LSF (see Fig. 4.5). Some LSF wastes undergo substantial radioactive decay in storage (e.g., waste containing ^{125}I, ^{32}P, or ^{35}S) reducing or eliminating the radiological hazard, but most LSF in storage is being accumulated for future shipment and/or treatment.

Waste categories (Table 5.1) fall into four general classes — those with organic constituents, those with hazardous metals, aqueous corrosives, and an "Other" category containing complex mixtures and those wastes for which the hazardous constituent could not be determined from available data. The organics class is broken down to include LSFs, various organohalides, and a category to include the balance of organic constituents not covered by the other categories.

Similarly, the metals class is subdivided into categories for cadmium-, chromium-, lead-, and mercury-contaminated wastes.

In addition to the large quantity of LSFs discussed previously, organic chemicals found in mixed waste include chloroform, trichloroethane, methylene chloride, waste oils, CFCs, and other chlorinated organics used in research or as pesticides. CFCs are derived from dry cleaning, refrigeration, and other industrial operations. Waste oils are derived from vacuum pumps, other equipment and maintenance operations.

Mixed waste containing metals are generated through decontamination of lead used as shielding, from batteries, paint wastes, and lead-containing research solutions. Metal-bearing wastes also result from the use of chromium as a corrosion inhibitor in nuclear power reactors, as a cleaning agent, and as a waste treatment agent for ion-exchange resins. Other sources are cadmium-containing reactor control rods and grit blast. Mercury-contaminated equipment and debris, as well as mercury from laboratory experiments, are also sources of metal-contaminated mixed waste.

Aqueous corrosive mixed wastes are generated from a wide range of industrial and laboratory operations. These are primarily acids (over 90%); however, bases also make up a small percentage of this category. "Other" sources of mixed waste include biological wastes,[c] incinerator ash, filter bags, and trash (see Appendix D, Table D.11).

5.3 Mixed Waste Treatment Options

5.3.1 Land Disposal Restrictions

EPA regulations, known as the LDR, prohibit the disposal of hazardous waste (including mixed waste) unless the wastes are treated to EPA standards in 40 CFR 268 Subpart D or unless a variance or extension to an LDR effective date is granted. Hence mixed waste must be treated to the applicable treatment standard before land disposal is permitted. In general, EPA treatment standards for specific wastes are either expressed as concentration levels or treatment technologies. EPA's approach for developing treatment standards was established using BDAT. Mixed wastes are subject to the established treatment standards for the hazardous portion of the waste except for four categories of mixed waste that have a specified treatment technology as their treatment standard (radioactive lead solids, radioactive elemental mercury, radioactive hydraulic oil contaminated with mercury, and certain radioactive high-level wastes). Please note that the

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[c]The definition of mixed waste does not, generally, include biological waste. However, biological waste containing mixed waste *would* be considered as mixed waste. The "biological" category in this study includes waste reported by its source as mixed waste, with a description clearly designating the biological nature of the waste.

BDAT, used to set treatment levels, does not necessarily have to be the technology used to meet a treatment standard *unless the treatment standard is expressed as a specific technology.*[d]

5.3.2 Treatment Options

The treatment options evaluated for each mixed waste category are listed in Table 5.2. One or more individual treatments or sequences of treatments were identified for each waste category. Where the waste category contains two or more distinct streams, a treatment or treatment sequence is identified for each waste stream. The table also shows the hazardous constituents in each waste stream, the EPA waste code, the BDAT for treatment of the waste stream, as identified by the EPA, and the EPA treatment standard for the stream. Potential treatment schemes for each waste stream are shown under the column "Treatment Alternatives." These alternatives represent approaches that are considered as possibly feasible based on the capability of the technology to achieve the required treatment standard. The column entitled "Treatment Considerations" contains useful information pertaining to the treatment or to the waste stream. The last column, "Recommended Treatment," shows the treatment (or sequence) selected as the recommended treatment in this study. It must be stressed that, using a specific technology to meet treatment standards is mandatory when, and only when, the standard is a specified technology.

The treatment options appearing in Table 5.2 were evaluated based on information derived from several sources, including 40 CFR Part 268, and several reports.[1-5] The range of treatment options considered was compiled from these references, drawing on those technologies that have been demonstrated as meeting the EPA requirements for streams similar, as indicated by available stream property data, to those in this study (Table 5.2). For each stream, the recommended treatment was selected using the following criteria. The treatment must (1) satisfy regulatory requirements, (2) be economically feasible, and (3) be likely to become available within about a year, if not already offered commercially. It also needs to be noted that the options were evaluated on the basis of the hazardous waste and its hazardous constituents only. The radiological properties of the mixed waste stream and the present and future availability of any option to treat mixed waste may call into question the viability of the recommended treatment.

5.3.3 Selection of Recommended Treatment

Treatment, handling, and packaging requirements for the radioactive components of mixed waste depend on a knowledge of radionuclide identities and concentrations in the waste as well as the physical form of the waste, the radioactive waste class (i.e., Class A, B, or C), and the chemical form. For RCRA-regulated wastes, treatment requirements depend on a knowledge of the EPA

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[d]For further information on the LDRs, please refer to OSWER Directive 9555.00-01, "Guidance on the Land Disposal Restrictions' Effects on Storage and Disposal of Commercial Mixed Waste," September 1990.

waste codes provided in 40 CFR Part 261 and the EPA treatment standards if the waste is determined to be LDR under 40 CFR Part 268.

Once classified by EPA waste code, physical form, radionuclide, and NRC waste class, the treatment for each waste can be identified. Minimum waste form and stability requirements for radioactive waste are specified in 10 CFR Part 61. Certain mixed wastes fit into special waste groups (e.g., certain high-level radioactive waste, contaminated lead solids, or mercury) with treatment standards as specified technologies.

EPA waste codes, EPA treatment standards, and concentration levels of contaminants (for wastes with treatment standards that are specified as concentration levels) were the key factors in categorizing waste streams for treatment selection. These data and information on waste forms were obtained from the survey. It must be noted that the data used in this study vary widely in the amount and quality of information available for each waste stream. In particular, individual radionuclide concentrations for wastes with multiple isotopes were usually not obtainable from the completed survey questionnaires. In addition, EPA codes were not consistently provided by the generator. Since determining EPA code or codes that apply to a waste requires considerable knowledge of RCRA regulations, it is also likely that some of the EPA codes provided are not entirely accurate or complete. For these reasons, some EPA codes have been inferred from the stream description.

The recommended treatments selected for mixed waste in this work are shown in the last column of Table 5.2. In selecting a treatment for a given waste, EPA standards were first consulted. The existence of a standard specified as a technology, such as macroencapsulation for lead shielding, leaves no option. The specified treatment technology must be selected unless a variance from a treatment standard is granted pursuant to 40 CFR 268.44. In other cases, possible treatment options for the waste were compiled from prior studies,[1-5] using alternatives previously developed for similar wastes. Final selection was made giving preference to the BDAT and current availability but also taking into account economic feasibility and likelihood of future availability.

Incineration is recommended for most of the wastes in the *organics* class, including LSFs, oils, chlorinated organics, and fluorinated organics. Incineration is the BDAT for all of the organic mixed waste in this study, except for waste oils, for which a BDAT has not been established and which is not a Federally listed hazardous waste.[e] However, it may be possible to

[e]EPA has decided not to list used oil destined for disposal as hazardous waste, considering the existing regulations and controls to be adequate to ensure that used oil does not pose a threat to public health and the environment. However, used oil may still be declared a hazardous waste if if exhibits a toxic characteristic. States have the right to impose additional controls, some of which have done so in their decision to designate used oil as a hazardous waste.

increase the percent incinerated through judicious blending with other incinerable organics. The corrosive nature of incinerator emissions from highly halogenated CFCs make incineration less feasible, since facility emission limits are likely to be exceeded. Incineration was selected for only 5%[f] of CFCs. The treatment selected for the remaining 95% of CFCs is distillation, followed by chemical oxidation. The "Other organics" category consists mostly of materials for which the BDAT is incineration or deactivation (which may include incineration).

The *metals* class requires a more diverse set of treatments than the *organics* class. Cadmium-contaminated waste may be stabilized in cement or glass. Chromium wastes, consisting mainly of chromium-contaminated solutions, can be chemically reduced, followed by precipitation, filtration, and stabilization. Neutralization of the filtrate following precipitation may be required. Three types of lead-contaminated wastes required different treatment sequences. Lead shielding that cannot be decontaminated and reused must be macroencapsulated. Lead-bearing solutions should be precipitated filtered and the precipitate stabilized. Again, neutralization of the filtrate following precipitation may be required. Lead batteries, not prevalent in the study (0.5 ft^3), may require thermal recovery of the lead. The mercury category consisted of two types of streams: (1) aqueous solutions, which may be precipitated and stabilized, and (2) equipment and debris contaminated with undetermined levels of mercury, for which the treatment required[g] is thermal recovery. However, based on the radiological properties of these wastes and the present and future availability of facilities that offer thermal recovery, this treatment may not be a viable option.

The selected treatment for "Aqueous Corrosives," consisting primarily (greater than 90%) of inorganic acids and bases, is neutralization. Incineration, however, is also a feasible option for aqueous streams burned in combination with high-heat-value streams.

The "Other" class is more difficult to assign treatments to, since wastes in this class have multiple or unusual contaminants. Wastes have been grouped (and numbered) within this class to the extent possible, and treatment options were identified based on the limited information available, as indicated in the "Treatment Alternatives" column. The metal-contaminated organic sludges (group 1) could be treated by distillation to recover solvents and followed by oxidation and stabilization of the residue. Incinerator ash (group 2), metal alloys (group 3), and sealed sources (group 8) are good candidates for stabilization. The aqueous, metal-bearing solutions (group 4) in

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[f]Only monochloromonofluorocarbons are assumed to be acceptable for incineration.

[g]The conservative assumption that the mercury level is high for these wastes is made since the actual level is not known. For low mercury contamination levels (below 260 mg/kg Hg), the BDAT selected would be to acid leach, then oxidize, followed by dewatering. If elemental mercury is present, the treatment standard is amalgamation.

this class are more complicated than those in the metals class above, but it should be possible to treat them the same way, although with more difficulty, using precipitation, filtration, and stabilization, with possible neutralization of the filtrate. Treatment selections for groups 5-6 are not possible, given the data available.

5.4 The Demand for Treatment Services

Table 5.3 summarizes some of the results of Table 5.2, presenting estimates of the demand, in cubic feet, for treatment services by the different waste types encountered in this study. Some waste categories require more than one technology. The demand shown in Table 5.3 is defined as the sum of the 1990 annual generation rate for the waste and the amount of waste in storage at the end of 1990.[b] In other words, this quantity represents the amount of capacity that would have to be provided to treat the annual waste generated and eliminate the 1990 inventory in one year. This demand figure is chosen in light of the strong regulatory incentive against storage of mixed waste.

The total demand for the different treatments is shown across the bottom row of Table 5.3, above the solid bar. Incineration, by far, is in greatest demand at 142,745 ft^3 for organic and other materials. Stabilization is second highest at 42,514 ft^3. Next in demand is a sequence to distill and oxidize organic sludges, in the amount of 17,486 ft^3. Neutralization, macroencapsulation, and chemical reduction are next in demand, estimated at 13,847 ft^3, 4,124 ft^3, and 2,885 ft^3, respectively. The demand for thermal recovery for mercury and lead acid batteries is estimated at 366 ft^3. Lead decontamination could have a demand up to 4,124 ft^3.

[b]The demand for storage has been determined using the same distribution of demand within each waste category as was obtained for generation. This assumption could result in underestimation of the demand for certain problematic wastes.

5.5 Profiles of Mixed Waste Treatment Industries

5.5.1 Overview of Existing Treatment Capability

Facilities for treatment of mixed waste have been developed at research laboratories, such as those operated by the DOE, and within the commercial sector. Examination of existing[i] (see Table 5.4) and future capability for treatment of commercial low-level radioactive mixed waste follows. DOE capabilities and facilities for treating mixed waste are not discussed in this report. In a recent Federal Register notice[j] regarding a case-by-case request by DOE to extend the LDR effective date for some of its mixed wastes, a discussion is provided on DOE's use of commercially available mixed waste treatment capacity. The feasibility and extent of DOE's possible use of commercial mixed waste treatment capacity is beyond the scope of this report. However, because of the large volume of mixed waste DOE generates annually, and has generated in the past, relative to commercially generated mixed waste, the possible use of commercial treatment capacity by DOE must be noted because it may impact the availability of commercial mixed waste services to the commercial mixed waste generators that is being discussed in this report.

Four commercial facilities currently treat LSF, the largest volume of mixed waste generated (Table 5.1). The Quadrex[k] Corporation facility, located in Gainesville, Florida, can process up to about 4,500 drums per month or nearly 400,000 ft^3 annually. Diversified Scientific Services, Inc. (DSSI), located in Kingston, Tennessee, provides incineration capacity of up to 130,000 ft^3 year for LSFs and bulk organics. Another LSF treatment facility, operated by RAMP Industries and located in Denver, Colorado, provides incineration and other treatments, up to 25,000 ft^3/year. NSSI/Recovery Services, Inc. (NSSI), located in Houston, Texas, accepts LSF materials and has substantial capacity (~750,000 ft^3 annually) for bulking and storage prior to off-site incineration. NSSI has storage for over 33,000 ft^3 of drummed wastes.

The pertinent operating license(s) and/or permit(s) should be consulted to determine the facility's treatment process or processes and the acceptable wastes. Appendix G contains portions of the radioactive materials and hazardous waste permits indicating radioactive and hazardous constituents that may be accepted for each commercial mixed waste treatment facility.

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[i]Vendor capacities are based on information provided by the vendors via personal communication in June 1992. **This report is dependent on vendor-stated capacity estimates, which were not verified.**

[j]"Hazardous Waste Management System: Land Disposal Restrictions (LDR); DOE Mixed Wastes Extension Application," Federal Register, Vol. 57, No. 101, Tuesday, May 26, 1992.

[k]Mention of specific products and/or manufacturers in this document implies neither endorsement, preference, nor disapproval by the U.S. Government or any of its agencies or contractors.

5.5.2 Quadrex

The Quadrex Corporation accepts only scintillation liquid, which is bulked by crushing to extract liquid from the vials and stored for accumulation prior to treatment off-site. The liquid, considered a hazardous waste in the state of Florida, is mainly burned off-site for energy recovery at cement kilns.

Quadrex is a TSD facility that fuel blends LSF and holds a Part B storage permit for LSF from the Florida Department of Environmental Regulation (FDER). Quadrex also has a radioactive materials license with the state of Florida which limits storage of radioactive materials to 180 d. The license includes standards for ^{14}C and tritium, allowing disposal of these isotopes as nonradioactive material, provided the activities of ^{14}C and tritium are below 0.05 μCi/g. A list of isotopes acceptable by Quadrex may be found in Appendix G. Quadrex is limited to 100 mCi/year for all isotopes other than ^{14}C and tritium in the material it processes for incineration. Because of this limit, some LSF waste with higher-than-normal activity is sent to NSSI for processing. NRC and Florida regulations allow the disposal of ^{14}C and tritium in LSF in concentrations <0.05 μCi/g without regard to its radioactivity (i.e., as a nonradioactive waste).

Quadrex is considering expanding the type of mixed waste it will accept for processing. The additional wastes that Quadrex is planning to treat are radioactively contaminated solvents similar to LSFs and radioactively contaminated oil. This additional treatment capability will require FDER approval of requests for amendment to Quadrex's treatment, storage, and disposal (TSD) permit.

5.5.3 RAMP

RAMP Industries processes both mixed waste and low-level radioactive waste. The mixed waste currently comprises 10 to 15% of its business. Mixed wastes accepted by RAMP include those containing only spent solvent wastes (F-series) and ignitable (D001) hazardous wastes. The F-series wastes include mostly halogenated and nonhalogenated organic solvents. Mixed wastes are bulked using a crusher/shredder to remove liquid from the vials, and stored for accumulation prior to treatment off-site. Classified as a hazardous waste in the state of Colorado, the LSF wastes are transferred locally to Chemical Waste Management, Inc., for recovery of toluene and other solvents by solvent extraction. The remaining liquid is considered nonradioactive and is transported to a permitted hazardous waste cement kiln for use as an energy recovery fuel. RAMP performs other treatment of mixed waste including compaction, neutralization, stabilization in cement, and solidification, but is limited by the hazardous waste codes of the wastes it can accept (see Appendix G).

RAMP is a TSD facility with interim status and has submitted an application for a Part B Permit to the Colorado Department of Health's (CDH) Waste Management Division. RAMP also holds a radioactive materials license, administered by the Radiation Control Division of CDH, for its radioactive waste operations.

5.5.4 NSSI/Recovery Services, Inc.

NSSI/Recovery Services, Inc. (NSSI) is a radioactive waste storage and processing facility that holds a radioactive materials license as well as a Part B Permit to store and process wastes. NSSI operates a multi-process treatment facility for radioactive and mixed waste. NSSI is currently accepting mixed waste that contains hazardous waste classified as D-series (characteristic) waste; F-, P-, and U-series (listed) waste in lab pack form; and all F-series (listed spent solvent) waste except F004 (spent non-halogenated solvents) and F006 (electroplating sludges). Wastes received by NSSI may be processed in the following ways:

- store and/or repackage wastes and accumulate them for off-site disposal,
- process and store wastes to prepare them for off-site disposal,
- process mixed waste to remove hazardous characteristics, and
- recycle wastes as fuels or as other beneficial products.

Liquid wastes received in bulk containers are tested for their compatibility and then transferred to appropriate tanks for storage and processing. Waste characteristics determine the types of processes and sequence to which they are subjected. Treatment processes allowed by their RCRA permit include chemical fixation to stabilize waste for land disposal, chemical oxidation/reduction to destroy hazardous organics, activated carbon which removes organic contaminants by adsorption onto solids, neutralization, and precipitation. Mechanical separation is used to sort lab packs. Decanting is used to separate liquids of varying densities. Solvent recovery segregates and consolidates solvents for recycling, and evaporation is used to dry sludge. LSFs and other similar organics are considered nonradioactive and are transferred off-site to a fuel broker, Gibraltar Corporation, for use as cement kiln fuel at a number of locations throughout Texas.

NSSI currently treats and stores radioactive wastes under its Radioactive Materials License administered by the Texas Department of Health. The license includes standards for ^{14}C and tritium that are similar to Florida's standards, allowing disposal of LSF containing these isotopes as nonradioactive material (i.e., as hazardous waste only) provided the activities of ^{14}C and tritium are below 0.05 μCi/g. The mixed waste that NSSI can accept are governed by the allowable

hazardous components as specified in its RCRA Part B Permit on file with the Texas Water Commission. NSSI is RCRA permitted to store and treat the hazardous wastes from an extensive list (see Appendix G) but is not allowed to dispose of mixed waste on-site. Chemical and radiological waste profiles are required by NSSI for all types of wastes it receives.

5.5.5 Diversified Scientific Services, Inc.

Diversified Scientific Services Incorporated (DSSI) has a boiler facility operating under RCRA interim status to treat mixed waste containing category F001 to F005 (spent solvents) and characteristic solvents. The facility includes a cogeneration plant, the boiler for which provides heat for steam turbines to generate electric power. Complete combustion is promoted by injection of ignitable fluid waste into the boiler by means of an atomizer, or mechanical spray device, leaving very little ash residue. Stack gases pass through a scrubber, baghouse, and High Efficiency Particulate Air (HEPA) filter to remove particulates and are monitored for radioactive particles. This waste fuel boiler has been operational since 1991 and is operating under a state interim-status-boiler permit. Other materials, such as plastic or glass scintillation vials are recycled for beneficial reuse.

The DSSI facility accepts primarily LSF and other ignitable solvents, such as halogenated organics. DSSI has a RCRA Part B Permit which allows storage of mixed waste for radioactive decay, and a radiological byproduct materials license, which limits the quantity of isotopes (see Appendix G) that may be on-site at any given time.

5.6 Potential Mixed Waste Treatment Facilities

5.6.1 Scientific Ecology Group

Scientific Ecology Group (SEG) is likely to begin accepting certain types of mixed waste in the next 2 years. Located in Oak Ridge, Tennessee, SEG provides radioactive waste management services including incineration and is submitting an application for a RCRA Part B Permit in order to process mixed waste.

SEG currently operates a multi-process facility for treatment of low-level radioactive waste. Wastes are sorted and segregated depending on the homogeneity of the waste shipment received. A solidification unit exists for sludges and slurries. Oil, and other wastes that are non-RCRA hazardous wastes, can be treated as LLRW (non-mixed) in Tennessee. Wastes with a halide content exceeding 5% by weight, however, cannot be incinerated at SEG since the off-gas filtration equipment cannot handle high concentrations of acid gases. The incinerator operates at 900 to 1,600 lb/h of solid waste and can simultaneously burn 30 gal/h of radioactive, nonhazardous waste oil. The SEG incinerator includes a secondary chamber with a 3-s gas residence time and a

temperature of 2,200°F to achieve a 99.9999% destruction and removal efficiency (DRE) of volatile organics.

The SEG incinerator is equipped with a baghouse and dual HEPA filters for particulate removal and a wet scrubber for acid gas removal. SEG expects to achieve a volume reduction through incineration of over 100:1 for mixed waste, similar to that currently realized with combustible radioactive waste.

SEG currently has a radioactive materials license from the Tennessee Department of Health and Environment. This license restricts possession of radioactive materials to a period of 180 d, precluding storage of mixed waste for decay as part of its treatment process. SEG has prepared and is submitting an application for a RCRA Part B Permit to allow incineration of mixed waste and hopes to have this permit within 2 years.

In the future, the facility will be capable of processing mixed waste if SEG obtains a RCRA Part B Permit. Much of the organic mixed waste could be incinerated in the SEG incinerator, which is patterned after a Studsvik unit in Sweden used for incinerating radioactive waste. SEG is developing a vitrification system that will glassify the incinerator ash into glass blocks that should be capable of passing all characteristic tests used for defining hazardous wastes.

5.6.2 Envirocare

Envirocare of Utah, Inc., operates a low-activity radioactive and mixed waste disposal (burial) facility and is planning to offer mixed waste treatment in the future. Envirocare has already received a RCRA Part B Permit from the Utah Division of Solid and Hazardous Waste, allowing the receipt, storage, and disposal of low-activity wastes which are both radioactive and hazardous at its South Clive facility. With its Part B Permit, Envirocare may store and dispose of solid-phase mixed waste (see Appendix G for specific limits).

5.7 Comparison of Treatment Capacity Versus Demand

Treatment services offered by companies in the commercial sector, along with their estimated annual treatment capacities, are shown in Table 5.4. Figure 5.2 presents the combined capacity, by treatment technology, for the four companies that currently have the capability to treat mixed waste. For the waste streams reported in the Mixed Waste Profile, the information available on hazardous constituent concentration levels, on a stream by stream basis, is limited. For this reason, comparison of hazardous constituent concentrations with specific acceptance criteria for each treatment facility cannot be made. Rather, the capacity available currently to treat each waste category is compared to the demand, with the goal of finding where capacity needs to be developed for mixed waste treatment. Figure 5.3 shows a comparison of the demands

listed in Table 5.3 with commercial treatment capacities that are currently available. Demand is defined as 1990 generation rate plus material in storage at the end of 1990. This is a conservative estimate of needed capacity because some of the waste in storage is being accumulated for treatment on-site or for shipment to off-site treatment facilities. Drawing on the data in Tables 5.3 and 5.4, the following observation can be made.

5.7.1 Availability of Incineration Capacity

a. LSF — The four industries, NSSI (capacity 750,000 ft^3), Quadrex (capacity 400,000 ft^3), DSSI (capacity 130,000 ft^3), and RAMP (capacity 25,000 ft^3), together provide 1.28 million ft^3 of annual capacity to treat LSF. This amounts to nearly 13 times the amount generated annually (100,196 ft^3) and can easily accommodate the stored LSF as well. Most, but not all, LSF are acceptable depending on radionuclide content.

b. Waste Oil — Waste oil destined for disposal and not exhibiting a hazardous characteristic is not considered as mixed waste by EPA and can currently be incinerated without a RCRA permit. The 5,259 ft^3 generated annually could be accepted by any of the four industries offering LSF treatment, and the radioactive waste oil could also be accepted by SEG, provided the waste oil stream is tested and no listed or characteristic hazardous waste component is present.

c. Halogenated Organics — RAMP accepts organohalides, with concentration limitations, and processes them for incineration. Chlorinated organics, fluorinated organics, and low-halogen CFCs may be incinerated, based on current practice. CFCs with high halogen content, however, are not accepted for incineration. The 2,704 ft^3 of incinerable organohalides (2,504 ft^3 of chlorinated organics and 5% of 3,998 ft^3 of chlorinated fluorocarbons) generated annually could be accepted by RAMP for incineration.

d. Other Organics — These wastes, generated at a rate of 9,697 ft^3/year, are primarily D001, F003, and F005 wastes for which incineration is the selected treatment. This type of waste could be accepted by RAMP, with a capacity of 25,000 ft^3/year (incineration).

e. Lead penetration sealants and oils — Penetration sealants and oils contaminated with lead, generated at a rate of 29 ft^3/year, are not accepted for incineration by any of the existing commercial facilities. The demand for treatment of this waste is estimated to be small (78 ft^3 or 1% of 7,782 ft^3 of lead wastes).

5.7.2 Availability of Stabilization Capacity

Stabilization of solid mixed waste is provided by RAMP and NSSI. Their joint capacities of 112,000 and 5,000 ft^3/year, respectively, exceed the total estimated demand (42,514 ft^3/year) for stabilization. Hence, metal-contaminated solutions can be treated by these two companies, with the major capacity being provided by NSSI.

5.7.3 Availability of Neutralization Capacity

NSSI (capacity 10,000 ft^3/year) and RAMP (capacity 6,000 ft^3/year) provide a total capacity for neutralization of aqueous corrosives of 16,000 ft^3/year, enough to accommodate the demand (13,847 ft^3) for this waste class.

5.7.4 Availability of Capacity for Distillation/Oxidation of Organics

CFCs with high halogen content and metal-contaminated organic sludges present a problem for most commercial vendors. NSSI can treat such wastes by distillation to recover organics and then oxidation with stabilization of the residue. NSSI's capacity to treat organic sludges in this way is estimated at 10,000 ft^3/year. This capacity would accommodate the estimated generation rate for CFCs with high halogen content (3,800 ft^3/year or 95% of 3,998 ft^3/year of chlorinated fluorocarbons) and CFC sludges from the *Other Hazardous Materials* category (3,500 ft^3/year or 33% of 10,613 ft^3/year of other hazardous materials) with some reserve capacity. However, NSSI's capacity would fall short of the demand (17,486 ft^3) by about 7,500 ft^3.

5.7.5 Availability of Capacity for Decontamination/Macroencapsulation of Lead

Decontamination of solid lead such as radiation shielding, provided the radioactivity is limited to the surface, is provided by NSSI. Macroencapsulation or stabilization of lead, sealed sources, and some other materials is available from NSSI, provided that waste handling does not require hot cell work based on exposure rate. The capacity of 300 lb/d for decontamination or macroencapsulation of lead (~100 ft^3/year) is substantially less than the annual generation rate (1,528 ft^3/year or 53% of 2,883 ft^3/year of lead) and falls short of the demand (4,124 ft^3) by about 4,000 ft^3.

5.7.6 Availability of Capacity for Chemical Reduction of Chromium Wastes

NSSI has the capability for chemical reduction of wastes contaminated with chromic acid and chromates, with a capacity of 10,000 ft^3/year. This capacity exceeds the estimated demand of 2,885 ft^3/year.

5.7.7 Thermal Recovery of Mercury and Lead

No commercial services are offered for treatment of mercury-contaminated waste, generated at 49 ft^3/year (or 11% of 442 ft^3/year of mercury); or for lead batteries, generated at less than

1 ft^3/year (from mixed waste database), for which thermal recovery is indicated as a treatment standard. These are small streams (estimated demand is 366 ft^3/year) for which no commercial treatment alternatives exist. Thermal recovery is the EPA treatment standard for D008 lead characteristic hazardous waste from lead acid batteries and for D009 nonelemental mercury-contaminated materials. However, thermal recovery for these mixed wastes may not be a viable option because of their radioactive component.

5.7.8 Summary of Current Waste Treatability Capacity

The estimated demand for treatment services is summarized in Table 5.3 by waste category. These were compared with the treatment capabilities of commercial industries presented in Table 5.4. The findings of this comparison are illustrated in Fig. 5.3 and are summarized below. It should be emphasized that some of the conclusions reached here may be based on one-time generations of unique mixed waste streams; therefore, caution should be exercised in extrapolating these results to present or future treatment needs.

There appears to be adequate incineration capacity available to meet the demand for LSF, waste oil, chlorinated and fluorinated organics, and other organics, except for CFCs. Enough capacity exists to treat CFCs generated annually by distillation and oxidation, but additional capacity, estimated at 7,500 ft^3, would be needed to treat CFCs generated *and* in storage at the end of 1990. Sufficient capacity exists to stabilize metal-bearing solutions, metal alloys, and sealed sources. There is adequate existing capacity available for precipitation, neutralization, and chemical reduction, but capacity is needed for decontamination and macroencapsulation of lead shielding (about 4,000 ft^3) and to treat other wastes contaminated with solid lead and mercury (366 ft^3) by thermal recovery.

The volume of wastes requiring added capacity to match their generation rate is estimated at about 1,600 ft^3 annually. The total unmet demand is estimated at about 12,000 ft^3 (storage and generation over a 1-year period).[1]

It should be clearly understood that the facility capacities presented in this report represent information as provided by the companies themselves. These capacities are, to some degree, theoretical as they have never actually been demonstrated, and they do not take into account any mitigating factors that may affect actual capacity. Such factors may include the need for pretreatment or unusual physical preparation, including unanticipated chemical analyses. Also, the timing of treatment campaigns and any required downtime between campaigns may affect

[1]It is important to note that estimated capacities to treat mixed waste have been provided by the vendors that offer these services. Some overestimation or underestimation may have occurred since most of the needed treatment diversity is provided by only two vendors, with the majority of the capacity provided by only one. It may be impractical for NSSI to provide all of the capacity that it has estimated.

throughput. Additional factors that may limit total capacity are the resource and manpower limitations that operating parallel processing lines may impose on those facilities providing multiple treatment options. Finally, as mentioned previously, DOE's possible use of commercial facilities may affect their availability for use by the commercial sector.

5.7.9 Estimated Future Treatment Capacity

Over the next 5 years, as many as two additional facilities could be permitted for the treatment of liquid mixed waste, including technologies other than incineration. Currently, four facilities can accept LSFs; this may increase to five if SEG receives its Part B Permit. Existing facilities have expanded the list of wastes they can accept or are in the process of doing so. Hence, the capacity for treating mixed waste appears to be increasing.

NSSI considers itself a pilot operation and is willing to develop and test new technologies. New processes to be developed at NSSI, or at other facilities, could employ one or more of the promising advanced technologies. Technologies that may have application to treatment of mixed waste include supercritical water oxidation, ultraviolet (UV) light/oxidation, wet air oxidation, and solvent extraction[2]. New technologies such as these may be demonstrated in the near future. A detailed listing of new and emerging technologies for mixed waste treatment is provided in Appendix H.

6 Summary and Conclusions

6.1 National Profile...

The survey of potential commercial mixed waste generators in the United States consisted of a series of well-defined steps that included: (1) selecting a total number of facilities to be sampled, basing the number on an anticipated 25% nonresponse rate and a 10% desired relative standard error; (2) sending out a detailed questionnaire (Appendix B) to a number [determined in (1)] of randomly selected facilities; (3) accumulating and compiling the responses, in an appropriate format, into a database; and (4) estimating the national commercial mixed waste generation rates based on multiplying the "raw" data by weighting factors to correct for the fact that only a fraction of the facilities in each group were sent questionnaires.

The survey target population (survey frame) included a total of 2,936 facilities after duplicates were eliminated. A random sample of 1,323 facilities was selected from this target population. Data from 1,016 completed mixed waste survey questionnaires (including 21 facilities which were determined to be no longer in business, a 77% response rate) received by ORNL

indicated that ~81,000 ft^3 of commercially generated low-level radioactive mixed waste was generated in the United States in 1990 by those surveyed. Approximately 63% of this reported volume was liquid scintillation fluid.

Using weighting factors to generate a statistically valid estimate of the 'national' mixed waste profile, it is estimated that ~140,000 ft^3 of low-level radioactive mixed waste were generated nationally in 1990 of which nearly 72% was LSFs. In addition, an estimated 75,000 ft^3 of mixed waste was in storage for various reasons as of December 31, 1990. The industrial category was estimated to be the largest generator and accumulator of mixed waste, with over 36% of the generation and nearly 57% of the storage, of the total mixed waste in the United States in 1990. Data received from 97% of the operating nuclear utilities (some may have multiple reactors) in the country indicated that they accounted for <10% of the estimated total 1990 generation rate and ~29% of the estimated mixed waste in storage.

Upper and lower bounds were set on the volume of mixed waste that is currently untreatable by making the assumption that LSF, oil, organic (not halogenated), and corrosive waste are treatable under current technologies. Deducting the wastes that are assumed to be treatable from the estimated national total mixed waste generation rate leaves ~18,500 ft^3 of untreatable commercial low-level mixed waste. Thus, with this as an upper bound and the estimated ~5,000 ft^3 of currently untreatable mixed waste (see Sect. 4.2.5) as the lower bound, the untreatable mixed wastes range from 3.5 to 13.3% of the estimated 1990 national generation rate of 140,000 ft^3.

Although Compact/State and Hazardous Waste Stream data are presented, it should be emphasized that the profile was generated to be statistically valid only at the national level and only for the major facility categories. It is estimated that the overall accuracy of the projected mixed waste generation rates and waste in storage are well within the objective of the study which was to be, at the 95% confidence level, within a factor of 2. Estimates of mixed waste volumes calculated at the state level may be less reliable, mainly due to fewer samples in these substrata.

6.2 The Treatability of Mixed Waste

A broad spectrum of mixed wastes were generated by the facilities surveyed in the National Profile, including liquid scintillation fluids, organohalides and other organics, wastes contaminated with toxic metals, corrosives, and other hazardous materials. A considerable inventory of mixed waste existed in storage as of December 31, 1990. These mixed wastes present a need for specific treatment services, including incineration, stabilization, chemical treatment, and recovery/reuse technologies. Four companies — NSSI (Houston, TX), DSSI (Kingston, TN), Quadrex

(Gainesville, FL), and RAMP (Denver, CO) — currently offer mixed waste treatment services for a limited spectrum of mixed waste. Two others, SEG (Oak Ridge, TN) and Envirocare (Salt Lake City, UT), may offer mixed waste treatment in the near future. A comparison has been made between the available treatment capacity and expected demands due to estimated mixed waste generation in 1990 plus mixed waste in storage at the end of 1990. Based on the estimated demand for treatment services for each waste generation category, in comparison with treatment capabilities of the industries identified in this report, sufficient treatment capacity appears to exist for all mixed waste categories except chlorinated fluorocarbons, lead shielding and other waste contaminated with solid lead, and mercury-contaminated equipment and debris. Sufficient capacity to treat all mixed waste requiring macroencapsulation is also not available. The capacity shortfall amounts to ~12,000 ft^3. Currently operating commercial treatment facilities may be able to handle nearly all of the commercial mixed waste generated, based on the reported 1990 generation data, but to address the total demand (computed as 1990 generation plus storage as of the end of 1990), some significant additional capacity must be developed to treat mixed waste already in storage.

Finally, it must be emphasized that the DOE generation and inventory of mixed waste and any DOE capabilities and DOE facilities for treating mixed waste (either commercial and/or DOE mixed waste) are beyond the scope of this study. Current and future demands that DOE will have for commercial mixed waste treatment services are also not covered in this study. (See 57 FR 22024, May 26, 1992, for information on DOE's efforts to contract for commercial mixed waste treatment services.) Thus any effect of DOE's current or future procurement of commercial mixed waste treatment services was not factored into the commercial low-level radioactive mixed waste treatment capacity determinations presented in this report.

A range of 5,000 to 18,500 ft^3 of untreatable mixed waste was estimated from the 1990 generation and storage data resulting from the survey questionnaire results. More specifically, Table 5.3 of Sect. 5, estimates the untreatable volume of mixed waste at 11,954 ft^3 after comparing treatment capacities with treatment demands in 7 waste categories. Given that some 75,000 ft^3 of mixed waste was estimated to be in storage as of December 31, 1992, the question arises: Why does so much mixed waste remain untreated? Although, some of the waste may only be in storage for accumulation prior to future treatment/disposal, possible reasons for other waste not being treated, based on discussions with survey participants, include:

- Generators believe that treatment facilities may be overestimating their capabilities, capacities, and possession of required permits.

- Small mixed waste generating facilities may not be aware of the identity or capabilities of commercial facilities that can treat mixed waste.
- Mixed waste generators may be knowledegable about the identity of treatment facilities but may have insufficient information to match their waste with the acceptance criteria of the treatment facilities.
- Generating facilities may not want to relinquish control over their waste without proper/legal assurances that may be difficult/impossible to obtain.
- Various regulations, as well as their interpretation by the individual states, make the legal landscape complex for mixed waste generators.
- Inexperience or limited experience with the management of mixed waste may cause generators to take longer to make required decisions to contact and contract with a company to treat their mixed waste.
- Waste may, indeed, be treatable to the extent noted in this report, and generating facilities are sending mixed waste to the treatment facilities, but resource (both manpower and funds) limitations make the transfer slow, costly, and sometimes institutionally difficult.

6.3 Comments

Comments and suggestions are to be directed to:

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U.S. Environmental Protection Agency
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7 References

1. "Hazardous Waste/Mixed Waste Disposal Facility-Recommended Treatments and Related Waste Management Issues," WSRC-RP-90-1143, November 1990.

2. "Final Conceptual Mixed Waste Management Plan," A report to California Department of Health Services and the states of the Southwestern Compact, by Ebasco Environmental, December 1989.

3. Kirner, N., G. Faison, and C. Owens, "Mixed Waste Management Options," DOE/LLW-134, December 1991.

4. "Final Best Demonstrated Available Technology Background Document for K031, K084, K101, K102, Characteristic Arsenic Wastes (D004), Characteristic Selenium Wastes (D010), and P and U Wastes Containing Arsenic and Selenium Listing Constituents, Volume 1," PB90-234014, May 1990.

5. "Final Best Demonstrated Available Technology Background Document for Characteristic Ignitable Wastes (D001), Characteristic Corrosive Wastes (D002), Characteristic Reactive Wastes (D003), and P and U Wastes Containing Reactive Listing Constituents, Volume 2," PB90-234022, May 1990.

6. "Regulating the Disposal of Low-Level Radioactive Waste, A Guide to the Nuclear Regulatory Commission's 10 CFR Part 61," Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, August 1989.

Table 4.1 Mixed waste survey: Operational statistics

	Facility category[1]					
	Academic	Government	Industrial	Medical	Nuclear utilities	Total
Number in sampling frame						
Known or potential generators	108	20	164	74	78	444
LLRW shipper lists	165	74	822	349		1,410
NRC license with EPA permit	73	4	166	19		262
NRC license without EPA permit	92	147	518	63		820
Subtotal	438	245	1,670	505	78	2,936
Number receiving questionnaires						
Known or potential generators	108	20	164	74	78	444
LLRW shipper lists	165	74	324	92		655
NRC license with EPA permit	73	4	24	1		102
NRC license without EPA permit	30	52	37	3		122
Subtotal	376	150	549	170	78	1,323
Number in data base						
Known or potential generators	80	17	133	53	76	359
LLRW shipper lists	111	61	250	65		487
NRC license with EPA permit	58	2	18	1		79
NRC license without EPA permit	18	40	31	2		91
Subtotal	267	120	432	121	76	1,016
Number reporting mixed waste[2]						
Known or potential generators	63	11	64	37	53	228
LLRW shipper lists	72	21	78	17		188
NRC license with EPA permit	16	0	0	0		16
NRC license without EPA permit	1	15	6	1		23
Subtotal	152	47	148	55	53	455

[1]As defined by Mixed Waste Profile Team prior to survey.
[2]Generation only.

Table 4.2 Licensee facility categories and number of survey respondents

Facility category[1]	Number of respondents
Nuclear reactor facility	
Boiling Water Reactor	30
Pressurized Water Reactor	45
Research & test reactors	5
Medical (non-federal)	
Hospital	
<250 beds	7
250-750 beds	24
>750 beds	8
Unassigned hospital	12
Medical college/hospital	28
Laboratory	24
Research	37
Unassigned medical	9
Academic	
<10,000 students	121
10,000-20,000 students	54
>20,000 students	47
Unassigned academic	34
Industrial	
Manufacturing	
<50 employees	17
50-200 employees	28
>200 employees	40
Unassigned manufacturing	3
Research & development	146
Decontamination & waste reduction	14
Sealed source/gauge/instrument user	11
Waste broker/processor	6
Nuclear fuel cycle (nonreactor)	1
Commercial radiopharmacy	6
Unassigned industrial	125
Government	
Federal	
Hospital	20
Research & development	45
Military	23
Unassigned federal	13
State	21
Other government	12
TOTAL	1,016

[1]As defined by respondents. Facility categories were, in some cases, different than the original assignment shown in Table 4.1.

Table 4.3 National Mixed Waste Profile
[Generation rate in 1990 (ft^3/year)]

	As reported[1]	Weighted[2]	Estimated standard error[3]
Academic	20,420	28,982	3,055
Government	18,324	26,500	5,978
Industrial	19,055	50,430	11,414
Medical	10,151	19,904	2,928
Nuclear utilities	13,276	13,625	703
TOTAL	81,226	139,441	13,579

[1]"As reported" values are shown for comparison purposes only and are not to be considered as the national mixed waste profile. "As reported" represents mixed waste reported by the 1,016 respondents to the survey questionnaire.

[2]"Weighted" represents the estimated mixed waste generation rate after correction of the "As reported" data for nonresponses and facilities not queried during the survey.

[3]"Estimated standard error" is calculated as described in Appendix E.

Table 4.4 National Mixed Waste Profile
[Amount in storage as of 12/31/90 (ft^3)][1]

	As reported[2]	Weighted[3]
Academic	3,874	5,447
Government	1,692	2,788
Industrial	16,078	42,281
Medical	1,158	2,227
Nuclear utilities	21,403	21,984
TOTAL	44,205	74,727

[1]This is <u>not</u> the amount requiring disposal. Some of this waste was being accumulated for treatment.

[2]"As reported" values are shown for comparison purposes only and are not to be considered as the national mixed waste profile. "As reported" represents mixed waste reported by the 1,016 respondents to the survey questionnaire.

[3]"Weighted" represents the estimated mixed waste generation rate after correction of the "As reported" data for nonresponses and facilities not queried during the survey.

Table 4.5 National Mixed Waste Profile
[Waste generated in 1990 that currently cannot be treated (ft^3)]

	As reported[1]	Weighted[2]
Academic	253	353
Government	1,183	1,455
Industrial	370	834
Medical	493	726
Nuclear utilities	1,432	1,470
TOTAL	3,731	4,838

[1]"As reported" values are shown for comparison purposes only and are not to be considered as the national mixed waste profile. "As reported" represents mixed waste reported by the 1,016 respondents to the survey questionnaire.

[2]"Weighted" represents the estimated mixed waste generation rate after correction of the "As reported" data for nonresponses and facilities not queried during the survey.

Table 4.6 National Commercial Mixed Waste Profile
[Generation rate in 1990 (ft^3/year)]

Weighted

	Hazardous waste stream												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other[1]	Total
Academic	26,919	15	512	0	0	251	44	0	5	0	71	1,165	28,982
Government	20,315	4	1,179	0	0	3,525	200	0	100	1	1,167	9	26,500
Industry	34,089	531	494	0	319	4,091	1,365	413	643	0	1,442	7,043	50,430
Medical	18,862	0	269	0	0	676	43	25	0	0	2	27	19,904
Nuclear utilities	11	4,709	50	0	3,679	1,154	1,231	4	254	8	156	2,369	13,625
TOTAL	100,196	5,259	2,504	0	3,998	9,697	2,883	442	1,002	9	2,838	10,613	139,441

[1]See Table D.11 in Appendix D for a listing of all "Other" streams reported being generated in 1990.

Table 4.7 National Commercial Mixed Waste Profile
[Amount in storage as of 12/31/90 (ft^3)][1]

Weighted

	Hazardous waste stream												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other	Total
Academic	4,289	6	201	0	0	526	30	1	1	0	68	325	5,447
Government	1,598	6	21	0	0	746	247	0	100	1	0	69	2,788
Industry	5,157	1,217	215	122	393	1,163	171	2,448	1,025	26,304	1	4,065	42,281
Medical	1,622	0	4	0	0	443	0	0	0	0	1	157	2,227
Nuclear utilities	168	5,061	512	0	8,600	1,284	4,451	416	757	11	361	363	21,984
TOTAL	12,834	6,290	953	122	8,993	4,162	4,899	2,865	1,883	26,316	431	4,979	74,727

[1]This is not the amount of mixed waste requiring disposal. Some of this waste was being accumulated for treatment.

Table 4.8 National Mixed Waste Profile
[Waste generated in 1990 that currently cannot be treated(ft^3)]

Weighted

	Hazardous waste stream												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other	Total
Academic	105	3	31	0	0	175	2	0	0	0	22	16	353
Government	794	0	13	0	0	375	173	0	100	0	0	0	1,455
Industry	2	21	90	0	1	63	148	40	0	0	0	469	834
Medical	330	0	0	0	0	3	8	0	0	0	0	384	726
Nuclear utilities	0	303	5	0	889	79	123	2	38	0	23	8	1,470
TOTAL	1,231	327	139	0	890	695	454	42	138	0	45	877	4,838

Table 4.9 State composition of the nine compacts (as of early 1992)

Compact	States
Northeast	Connecticut New Jersey
Appalachian	Pennsylvania West Virginia Maryland Delaware
Southeast	Alabama Florida Georgia Mississippi North Carolina South Carolina Tennessee Virginia
Central States	Arkansas Kansas Louisiana Nebraska Oklahoma
Midwest	Michigan[1] Indiana Iowa Minnesota Missouri Ohio Wisconsin
Central Midwest	Illinois Kentucky
Rocky Mountain	Colorado Nevada New Mexico Wyoming[2]
Southwest	Arizona California South Dakota North Dakota
Northwest	Idaho Washington Oregon Utah Alaska Hawaii Montana

[1]Michigan is included as a member of the Midwest Compact for the purposes of this study.

[2]Wyoming is included as a member of the Rocky Mountain Compact for the purposes of this study.

Table 4.10 Mixed waste generated in 1990
Weighted (ft^3)[1]

	Facility category					
	Academic	**Government**	**Industrial**	**Medical**	**Nuclear utilities**	**Total**
Northeast Compact (79)[2]	395	15	8,632	1,168	64	10,274
Appalachian Compact (136)[2]	2,664	14,216	12,443	854	1,425	31,602
Southeast Compact (132)[2]	4,448	4,438	7,416	4,061	2,757	23,120
Central States Compact (30)[2]	493	68	25	74	238	898
Midwest Compact (166)[2]	9,084	1,527	14,044	716	883	26,254
Central Midwest Compact (47)[2]	2,071	2,892	1,694	2,208	2,679	11,544
Rocky Mountain Compact (11)[2]	201	35	395	0[3]	0[4]	631
Northwest Compact (49)[2]	1,160	576	137	1,271	31	3,175
Southwestern Compact (125)[2]	3,729	206	3,292	4,146	5,142	16,515
Unaligned						
DC (11)[2]	192	1,958	0[3]	5	0[5]	2,155
ME (7)[2]	15	0[3]	0[4]	0[4]	115	130
MA (77)[2]	2,434	27	1,225	911	72	4,669
NH (3)[2]	0[3]	0[4]	0[3]	0[3]	0[4]	0[4]
NY (110)[2]	1,419	300	1,100	1,829	164	4,812
PR (0)[2]	0[6]	0[6]	0[6]	0[3]	0[5]	0[4]
RI (1)[2]	0[3]	0[3]	0[3]	0[4]	0[5]	0[4]
TX (27)[2]	380	242	27	2,661	27	3,337
VT (5)[2]	297	0[3]	0[4]	0[3]	28	325
TOTAL (1,016)[2]	28,982	26,500	50,430	19,904	13,625	139,441

[1]Weights applied were determined on a national basis for each of the facility subcategories and are not state/compact specific.
[2]Numbers in ( ) represent the number of facilites returning questionnaires within this compact/state.
[3]No facilities were surveyed in this particular category (e.g., no industrial facilities were surveyed in New Hampshire).
[4]At least one facility in this category within the compact/state returned a mixed waste survey questionnaire, and all facilities returning surveys in this category and within the compact/state reported generating no mixed waste.
[5]No facilities are present in this category within the compact/state (i.e., nuclear reactors in DC, PR, & RI).
[6]Facilities were surveyed in this category, but none of these facilities returned their surveys.

Table 4.11 Facility mixed waste profile – Academic[1]
Weighted (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid scintillation fluids	26,919	193	54,745	233	4,289
Waste oil	15	14	1	3	6
Chlorinated organics	512	54	411	31	201
Fluorinated organics	0	0	0	0	0
Chlorinated fluorocarbons (CFCs)	0	0	0	0	0
Other organics	251	105	40	47	526
Metals					
Lead	44	18	1	2	30
Mercury	0	0	0	0	1
Chromium	5	0	2	0	1
Cadmium	0	0	0	0	0
Aqueous corrosives	71	63	0	22	68
Other hazardous materials	1,165	41	176	16	325
TOTAL	28,982	488	55,376	354	5,447

[1]It should be noted that treatment and storage data are not necessarily additive since waste in either category may have been generated prior to 1990. Mixed waste that currently cannot be treated respresents waste which may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity.

Table 4.12 Facility mixed waste profile – Government[1]
Weighted (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid scintillation fluids	20,315	2,922	12,948	800	1,598
Waste oil	4	0	0	0	6
Chlorinated organics	1,179	0	0	13	21
Fluorinated organics	0	0	0	0	0
Chlorinated fluorocarbons (CFCs)	0	0	0	0	0
Other organics	3,525	5,651	107	369	746
Metals					
Lead	200	0	0	173	247
Mercury	0	0	0	0	0
Chromium	100	0	0	100	100
Cadmium	1	0	0	0	1
Aqueous corrosives	1,167	2	0	0	0
Other hazardous materials	9	0	0	0	69
TOTAL	26,500	8,575	13,055	1,455	2,788

[1]It should be noted that treatment and storage data are not necessarily additive since waste in either category may have been generated prior to 1990. Mixed waste that currently cannot be treated respresents waste which may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity.

Table 4.13 Facility mixed waste profile – Industrial[1]
Weighted (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid scintillation fluids	34,089	8,976	23,210	2	5,157
Waste oil	531	18	1	21	1,217
Chlorinated organics	494	25	159	90	215
Fluorinated organics	0	0	0	0	122
Chlorinated fluorocarbons (CFCs)	319	0	0	1	393
Other organics	4,091	1,432	1,635	63	1,163
Metals					
Lead	1,365	0	148	148	171
Mercury	413	27	0	40	2,448
Chromium	643	0	0	0	1,025
Cadmium	0	0	0	0	26,304
Aqueous corrosives	1,442	0	0	0	1
Other hazardous materials	7,043	3,463	284	469	4,065
TOTAL	50,430	13,941	25,437	834	42,281

[1]It should be noted that treatment and storage data are not necessarily additive since waste in either category may have been generated prior to 1990. Mixed waste that currently cannot be treated respresents waste which may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity.

Table 4.14 Facility mixed waste profile – Medical[1] Weighted (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid scintillation fluids	18,862	932	15,143	330	1,622
Waste oil	0	0	0	0	0
Chlorinated organics	269	0	169	0	4
Fluorinated organics	0	0	0	0	0
Chlorinated fluorocarbons (CFCs)	0	0	0	0	0
Other organics	676	3	149	3	443
Metals					
Lead	43	33	9	8	0
Mercury	25	0	25	0	0
Chromium	0	0	0	0	0
Cadmium	0	0	0	0	0
Aqueous corrosives	2	1	2	0	1
Other hazardous materials	27	0	0	384	157
TOTAL	19,904	969	15,497	725	2,227

[1]It should be noted that treatment and storage data are not necessarily additive since waste in either category may have been generated prior to 1990. Mixed waste that currently cannot be treated respresents waste which may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity.

Table 4.15 Facility mixed waste profile – Nuclear utilities[1]
Weighted (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid scintillation fluids	11	0	4	0	168
Waste oil	4,709	4,326	562	303	5,061
Chlorinated organics	50	0	0	5	512
Fluorinated organics	0	0	0	0	0
Chlorinated fluorocarbons (CFCs)	3,679	118	12	889	8,600
Other organics	1,154	15	7	79	1,284
Metals					
Lead	1,231	0	8	123	4,451
Mercury	4	0	0	2	416
Chromium	254	138	0	38	757
Cadmium	8	3	0	0	11
Aqueous corrosives	156	24	0	23	361
Other hazardous materials	2,369	168	2,274	8	363
TOTAL	13,625	4,792	2,867	1,470	21,984

[1]It should be noted that treatment and storage data are not necessarily additive since waste in either category may have been generated prior to 1990. Mixed waste that currently cannot be treated respresents waste which may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity.

Table 4.16 Facility mixed waste profile – All facilities[1]
Weighted (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid scintillation fluids	100,194	13,023	106,050	1,231	12,834
Waste oil	5,259	4,358	564	327	6,290
Chlorinated organics	2,504	79	739	139	953
Fluorinated organics	0	0	0	0	122
Chlorinated fluorocarbons (CFCs)	3,998	118	12	8,909	8,993
Other organics	9,697	7,206	1,938	695	4,162
Metals					
Lead	2,883	51	166	454	4,899
Mercury	442	27	25	42	2,865
Chromium	1,002	137	2	138	1,883
Cadmium	9	3	0	0	26,316
Aqueous corrosives	2,838	90	2	45	431
Other hazardous materials	10,613	3,672	2,734	877	4,979
TOTAL	139,441	28,764	112,232	4,838	74,727

[1]It should be noted that treatment and storage data are not necessarily additive since waste in either category may have been generated prior to 1990. Mixed waste that currently cannot be treated respresents waste which may be difficult, or even impossible, to dispose of because of a lack of acceptable treatment capability or disposal capacity.

Table 4.17 Compact/state generation of LLRW
(Generation and/or disposal in 1990)
(ft^3)

	LLRW disposed[1]	LLRW generated[2] As reported	Weighted
Northeast Compact	87,019	78,202	140,757
Appalachian Compact	119,579	212,120	359,347
Southeast Compact	333,488	266,507	296,971
Central States Compact	58,377	35,885	37,730
Midwest Compact	123,393	202,502	263,854
Central Midwest Compact	102,981	91,862	107,609
Rocky Mountain Compact	4,484	4,835	7,014
Northwest Compact	95,918	65,373	154,653
Southwestern Compact	84,934	65,744	80,638
Unaligned			
DC	530	1,373	3,762
ME	7,840	19,393	19,904
MA	40,613	27,673	34,576
NH	177	992	1,167
NY	71,303	42,496	51,986
PR	0	0	0
RI	177	0	0
TX	9,217	9,711	13,411
VT	0	174	259
TOTAL	1,140,030	1,124,842	1,573,638

[1]*Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 7, October 1991. Based on material provided by EG&G, Idaho to be published by the Low-Level Waste Management Program. IDB annual report data are based on actual "as received" manifest data from the three commercial burial grounds.

[2]National Mixed Waste Profile data are wastes shipped by LLRW generators and do not reflect any volume reduction activities by treaters or brokers prior to burial.

Table 4.18 Compact/state generation of mixed waste
[Generation rate in 1990 (ft^3/year)]

	Previous estimate[1]	Mixed Waste Profile as reported	Mixed Waste Profile weighted
Northeast Compact	3,010	1,782	10,274
Appalachian Compact	1,876	18,881	31,602
Southeast Compact	5,340	18,356	23,120
Central States Compact	185	688	898
Midwest Compact	2,772	12,482	26,254
Central Midwest Compact	2,183	6,338	11,544
Rocky Mountain Compact	0	264	631
Northwest Compact	173	1,706	3,175
Southwestern Compact	21,156	12,261	16,515
Unaligned			
DC	422	677	2,155
ME	0	122	130
MA	1,636	2,995	4,669
NH	0	0	0
NY	4,535	3,075	4,812
PR	0	0	0
RI	0	0	0
TX	7,520	1,373	3,337
VT	0	227	325
TOTAL	50,808	81,227	139,441

[1]National Profile on Commercially Generated Low-Level Radioactive Mixed Waste, Technical Letter Report for Task Two, March 31, 1991. Task Two Report generation data were derived from a wide variety of sources, including Governor Certifications, Compact/State Low-Level Waste Surveys, and Compact/State Mixed Waste Specific Surveys. Data quality, currentness, and match to National Mixed Waste Profile varied widely. **CAUTION** - Direct comparisons should not be made between individual compact state numbers.

Table 5.1. Mixed waste volume generation and storage in the United States for calendar year 1990[a]

Hazardous stream	Amount generated in 1990 (ft^3)	Amount in storage as of 12/31/90 (ft^3)	Hazardous constituents/source
Organics			
Liquid scintillation fluids (LSFs)	100,196	12,834	Liquid scintillation cocktails and similar radioactively contaminated organic solvents, such as toluene and xylene. Prevalent isotopes: ^{3}H, ^{14}C, ^{32}P, ^{35}P, ^{125}I, and ^{45}Ca.
Waste oil	5,259	6,290	Various pump, maintenance, and equipment soils contaminated with radionuclides: ^{137}Cs, ^{60}Co, ^{134}Cs, ^{3}H, ^{65}Zn, ^{54}Mn and/or ^{36}S.
Chlorinated organics	2,504	953	Chloroform, trichloroethane, methylene chloride, pesticides, chlorinated solvents, and other organochlorides contaminated with radioactive isotopes: ^{14}C, ^{3}H, ^{32}P, ^{35}S, and ^{125}I.
Fluorinated organics	0	122	No generation.
Chlorinated fluorocarbons (CFCs)	3,998	8,993	Freon, halogenated solvents and filters contaminated with CFCs from dry cleaning, refrigeration, degreasing, and decontamination operations. Isotopes present: ^{137}Cs ^{60}Co, and ^{54}Mn.
Other organics	9,697	4,162	Miscellaneous organic solvents, reagents and other organic compounds, plus materials such as rags, wipes, etc., contaminated with these compounds, primarily from research labs. Isotopes include: ^{14}C, ^{3}H, ^{32}P, ^{35}S, and ^{125}I.
Metals			
Cadmium	9	26,316	Grit blast from decontamination operations and activated reactor control rods. Isotopes include: ^{134}Cs, ^{137}Cs, and ^{60}Co. Inventory is mainly due to industrial sewer cleanup waste contaminated with ^{238}U.
Chromium	1,002	1,883	Chromium-contaminated solutions, including chromates or chromic acid from research, maintenance, and waste treatment (e.g., ion exchange). Isotopes include: ^{51}Cr and ^{60}Co.
Lead	2,883	4,899	Primarily lead shielding from nuclear applications and lead-bearing solutions from research labs, some of which are corrosive. Also stack ash, penetration sealant, oil, and other waste containing lead, including industrial batteries. Isotopes present: ^{125}I, ^{32}P, ^{137}Cs, and ^{60}Co.
Mercury	442	2,865	Mercury and equipment/debris contaminated with mercury, mostly lab derived. Most also exhibit characteristic of corrosivity. Isotopes present: ^{3}H, ^{14}C, and ^{125}I.
Aqueous corrosives	2,838	431	Inorganic and organic acids or, in some cases, bases, hazardous due to their corrosivity. Prevalent isotopes: ^{3}H, ^{32}P, ^{125}I, ^{14}C, ^{35}S, ^{60}Co, and ^{137}Cs.
Other hazardous materials	10,613	4,979	Various wastes including metal-contaminated organic sludges and aqueous solutions, incinerator ash, alloys, trash, chemicals, biological wastes, and sealed sources. Isotopes include: ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{60}Co, ^{137}Cs, ^{63}Ni, ^{125}I, ^{134}Cs, and ^{51}Cr.
Total	139,441	74,727	

[a]Adding the values in columns 3 and 4 produces an estimate of the demand for treatment as defined in this report. That is, the demand is defined as the sum of the annual generation rate and the amount of waste in storage at the end of the year.

Table 5.2. Mixed waste treatment alternatives – available options

Hazardous waste stream	Hazardous constituents or characteristics	EPA waste code	RCRA BDAT	Treatment standard (Specified technology or maximum contaminant level)	Treatment alternatives	Treatment considerations	Recommended treatment
Organics							
Liquid scintillation fluids 100,196 ft^3	Liquid scintillation cocktails and similar contaminated organic solvents. Prevalent isotopes:[a] ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{125}I, and/or ^{45}Ca	F Series (38%) D Series (11%) OTHERS (1%) UNKNOWN[b] (50%)	Incineration	Standard varies with solvent[c] (e.g., Toluene=0.33 mg/L and Xylene=0.15 mg/L) (40 CFR 268.41, Table CCWE)	Incineration OR chemical oxidation OR biotreatment	Must meet TCLP or total composition treatment standards. May burn as waste or boiler fuel supplement.	Incineration
Waste oil[e] 5,259 ft^3	Pump, maintenance, and equipment oils contaminated with radionuclides:[a] ^{137}Cs, ^{60}Co, ^{134}Cs, ^{3}H, ^{65}Zn, ^{54}Mn, and/or ^{35}S	F001 (4%) D001 (<1%) F002 (<1%) D018 (<1%) UNKNOWN[b] (95%)	None	None	Incinerate OR precipitate radionuclides THEN recycle oil	High fuel value makes incineration attractive.	Incineration
Chlorinated organics 2,504 ft^3	Chloroform, trichloroethane, methylene chloride, pesticides, chlorinated solvents, and other organochlorides. Isotopes:[a] ^{14}C, ^{3}H, ^{32}P, ^{35}S, and ^{125}I	D022 (58%) F003 (18%) F001 (9%) F002 (9%) UNKNOWN[b] (6%)	Incineration	Standard varies with solvent[c] (e.g., chloroform=5.6 mg/L, TCE=0.41 mg/L, and Methylene chloride=0.96 mg/L) (40 CFR 268.41, Table CCWE)	Incinerate	High concentrations of halides can cause air pollution control system corrosion. Standard for chloroform (D022) has not yet been set.	Incineration
Fluorinated organics 0 ft^3	No generation	No generation	Incineration		Incinerate	See comments for chlorine.	Incineration
Chlorinated fluorocarbons (CFCs) 3,998 ft^3	Freon, halogenated solvents and filters contaminated with CFCs from dry cleaning, refrigeration, degreasing, and decontamination operations. Isotopes:[a] ^{137}Cs, ^{60}Co, and ^{54}Mn	F002 (72%) F001 (25%) OTHERS (<1%) UNKNOWN[b] (3%)	Incineration	Standard varies with solvent[c] (e.g., Trichlorotrifluoroethane= 0.96 mg/L) (40 CFR 268.41, Table CCWE)	Incinerate OR distill THEN chemically oxidize	High halogen content precludes incineration for many CFC wastes, especially sludges. Chemical oxidation may require dilution of sludges.	*High halide content (95% of category):* Distillation THEN chemical oxidation *Low halide content (5% of category):* Incineration

Table 5.2. Mixed waste treatment alternatives – available options

Hazardous waste stream	Hazardous constituents or characteristics	EPA waste code	RCRA BDAT	Treatment standard (Specified technology or maximum contaminant level)	Treatment alternatives	Treatment considerations	Recommended treatment
Organics							
Other organics 9,697 ft^3	Misc. organic solvents, reagents and other organic compounds or materials like rags, wipes, etc., contaminated with such, primarily from research labs. Isotopes:[a] ^{14}C, ^{3}H, ^{32}P, ^{35}S, and ^{125}I	D001 (32%) F003 (31%) F005 (21%) UNKNOWN[b] (13%) OTHERS (3%)	Deactivation Incineration	Standards vary with hazardous component[c]	Incinerate OR otherwise deactivate to remove ignitability	Incineration is effective treatment for hazardous constituents appearing in wastes in this category.	Incineration
Metals							
Cadmium 9 ft^3	Grit blast from decontamination operations and activated reactor control rods. Isotopes:[a] ^{134}Cs, ^{137}Cs, and ^{60}Co	D006 (100%)	Stabilization OR recovery	1 mg/L (40 CFR 268.41, Table CCWE)	Thermal recovery of metal in industrial furnace OR stabilize in cement OR macroencapsulate		Stabilization in cement or glass
Chromium 1,002 ft^3	Chromium contaminated solutions, including chromates or chromic acid from research, maintenance, and waste treatment (ion-exchange) operations. Isotopes:[a] ^{51}Cr and ^{60}Co	D007 (82%) UNKNOWN[b] (18%)	Stabilization OR chromium reduction	5 mg/L (40 CFR 268.41, Table CCWE)	Stabilize in cement OR chemically reduce chromium THEN precipitate/filter THEN stabilize in cement.	Reducing agents and cement formulation depend on stream composition. Neutralization of filtrate may be required.	*Aqueous solutions:* Chemical reduction THEN precipitation/neutralization THEN stabilization in cement or glass

Table 5.2. Mixed waste treatment alternatives – available options

Hazardous waste stream	Hazardous constituents or characteristics	EPA waste code	RCRA BDAT	Treatment standard (Specified technology or maximum contaminant level)	Treatment alternatives	Treatment considerations	Recommended treatment
Organics							
Lead 2,883 ft^3	Primarily (53%) lead shielding from nuclear applications	D008 (89%) OTHERS (1%) UNKNOWN[b] (10%)	Macroencapsulation	Lead shielding *must* be macroencapsulated (40 CFR 268.42, Table 3)	Decontaminate/reuse OR macroencapsulate shielding	Macroencapsulation unit must comply with NRC radiation protection requirements.	*Lead shielding:* Decontamination and reuse OR macroencapsulation
	Lead-bearing solutions (41%) from research labs, some of which are corrosive		Stabilization	5 mg/L (40 CFR 268.41, Table CCWE)	Precipitate solutions THEN stabilize OR incinerate solutions	Lead shielding may be high-level radioactive waste.	*Aqueous solutions:* Precipitation THEN stabilization in cement
	Stack ash (4%), penetration sealant and oil (1%), and other waste (1%), including industrial batteries		Deactivate/lead recovery		Drain/precipitate/filter acid solutions THEN shred plates AND add filter THEN stabilize		*Acid batteries:* Recovery and stabilization
	Isotopes present:[a] ^{125}I, ^{32}P, ^{137}Cs, and ^{60}Co						
Mercury 442 ft^3	Mercury-bearing solutions	D003 (89%) D009 (11%)	Deactivation (solutions)	0.2 mg/L (40 CFR 268.41, Table CCWE)	Precipitate THEN filter solutions THEN neutralize filtrate AND stabilize filter.	Residues must meet numerical standard; hence, amalgamation may be required following recovery of Hg. Other treatment options (e.g., acid leaching) might be feasible but require a variance.	*Aqueous solutions:* Precipitate THEN filter THEN neutralize filtrate AND stabilize filter
	Equipment/debris (inorganics) contaminated with Hg, most are lab-derived and exhibit corrosivity. Isotopes present:[a] ^{3}H, ^{14}C, and ^{125}I		Mercury recovery	Roasting/retorting WITH recovery OR/AND amalgamation (40 CFR 268.42, Table 2)	Roast/retort WITH recovery OR/AND amalgamate elemental Hg THEN stabilize.		*High-Hg Inorganics:* Retort OR roast THEN amalgamate THEN stabilize

Table 5.2. Mixed waste treatment alternatives – available options

Hazardous waste stream	Hazardous constituents or characteristics	EPA waste code	RCRA BDAT	Treatment standard (Specified technology or maximum contaminant level)	Treatment alternatives	Treatment considerations	Recommended treatment
Organics							
Aqueous corrosives 2,838 ft^3	Inorganic and organic acids or, in some cases, bases, hazardous due to their corrosivity. Prevalent isotopes:[a] ^{3}H, ^{32}P, ^{125}I, ^{14}C, ^{35}S, ^{60}Co, and ^{137}Cs	D002 (99%) UNKNOWN[b] (1%)	Deactivation to remove corrosivity	Deactivation[c] to remove characteristic of corrosivity (i.e., 2.0 < pH < 12.5) (40 CFR 268.42, Table 2)	Acids: Recovery OR neutralization OR incineration Bases: Neutralization OR incineration	Over 90% of wastes in this category are acids, mostly inorganic.	Neutralization
Other hazardous material 10,613 ft^3	Misc. wastes including metal-contaminated (1) organic sludges (33%), (2) incinerator ash (32%), (3) Mg-Th alloys containing barium (11%), and (4) aqueous solutions (10%), (5) trash (10%), (6) various chemicals (1.3%), (7) biological[d] wastes (1.2%), (8) sealed sources (0.5%), and (9) others (1%). Prevalent isotopes:[a] ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{60}Co, ^{137}Cs, ^{63}Ni, ^{125}I, ^{134}Cs, and ^{51}Cr	*Multiple codes apply to most streams in this category, including:* D006 (35%) D008 (33%) D005 (11%) D002 (4%) D003 (2%) OTHERS (2%) UNKNOWN[b] (13%)	*Various technologies/ combinations apply:* (1) Depends on solvents and metals present (2) Stabilization (3) Deactivation (4) Deactivation (5) Deactivation (6) Deactivation (7) Deactivation (8) Macro-encapsulation	(1) Standards vary with contaminant[c] (2) as above (3) 100 mg/L barium (4) Standards vary with contaminant (5) as above (6) as above (7) as above (8) as above	(1) Incinerate THEN stabilize ash OR distill THEN oxidize THEN stabilize residue (2) Stabilize ash (3) Macroencapsulate OR stabilize (4) Precipitate THEN filter THEN stabilize OR incinerate (5) Possibly incinerate (6) Possibly incinerate OR biotreat OR oxidize (7) Possibly incinerate (8) Macroencapsulate OR stabilize *Other technologies may apply*	Wastes in this category are more complicated, generally having multiple hazardous constituents and/or characteristics, or are less well categorized. Accurate matching of treatments to these wastes requires more extensive data than is available.	*As applicable:* (1) Distill/recover organics THEN oxidize THEN stabilize residue (2) Stabilize ash (3) Stabilize in cement (4) Precipitate THEN filter solutions THEN stabilize filter cake in cement (5) Insufficient data (6) Insufficient data (7) Insufficient data (8) Stabilize in cement

[a]Prevalent isotopes are those occurring in a set of streams comprising at least 90% of the total number of streams for the current category. Isotopes are listed in order of decreasing frequency of occurrence. This information has been derived from National Profile data on streams treated in 1990, since isotope occurrence data for generation were not available by waste category.

[b]The designation UNKNOWN refers to waste for which the EPA code was not provided on the survey form, and there was not sufficient information describing the waste to infer an EPA code.

[c]The different contaminants appearing in this waste category are each subject to specific standards as put forth in 40 CFR 268 Subpart D.

[d]Some generators reported biological wastes in the mixed waste survey. Biological wastes do not fit the definition of mixed waste provided by NRC and the EPA, unless such waste *contains* mixed waste. The biological waste reported here as mixed waste is assumed to actually contain mixed waste.

[e]EPA recently published a final decision *not* to list used oil as a hazardous waste in 57 FR 21524, May 20, 1992.

Table 5.3 Treatment demand summary (ft^3) by waste category

Hazardous stream	1990 generation (ft^3)	Generation plus storage (ft^3)	Incinerate	Thermal recovery	Decontaminate/ macroencapsulate	Stabilize (cement/ vitrify)	Distill/ oxidize organics	Reduce chemically	Precipitate/ neutralize
Organics									
Liquid scintillation fluids	100,196	113,030	113,030						
Waste oil	5,259	11,549	11,549						
Chlorinated organics	2,504	3,457	3,457						
Fluorinated organics		122	122						
Chlorinated fluorocarbons	3,998	12,991	650				12,341		
Other organics	9,697	13,859	13,859						
Metals									
Cadmium	9	26,325				26,325			
Chromium	1,002	2,885				2,885		2,885	2,885
Lead	2,883	7,782	78	2	4,124	3,578			3,191
Mercury	442	3,307		364		2,943			2,943
Aqueous corrosives	2,838	3,269							3,269
Other hazardous materials	10,613	15,952				6,783	5,145		1,559
Total volume (ft^3)	139,441	214,168	142,745	366	4,124	42,514	17,486	2,885	13,847
Untreatable volume (ft^3)		11,954	78	366	4,024	0	7,486	0	0

Table 5.4 Current and potential future commercial industries treating mixed waste

Company/location	Contact	Telephone	Permits	Permitted materials	Description	Capacity[1]	Treatment technologies[1]
DSSI[2] P.O. Box 863 Kingston, TN 37763	Joseph Crider Jim McVey	(615) 376-0084	TN Radioactive License TN Part B Permit Cogeneration Permit Air Pollution Control Permit NESHAPS Permit	D001 and variety of F, P, and U wastes;[4] about 2000 isotopes (see also list in Appendix B)	Liquid scintillation materials and bulk organics	130,000 ft^3/year	Incineration[5]
NSSI[2] P.O. Box 34042 Houston, TX 77234	Bob Gallagher	(713) 641-0391	TX Radioactive License	Fully permitted (see also list in Appendix B)	Broad spectrum	750,000 ft^3/year 112,000 ft^3/year 10,000 ft^3/year 10,000 ft^3/year 300 lb/d 300 lb/d 150 gal/d (battery) Storage: 50,000 gal (tanks) 250,000 gal (drums)	LSF bulking/vial shredding Stabilization Chemical oxidation/ reduction Neutralization Cleaning/decontamination Macroencapsulation Neutralization/shredding/ macroencapsulation
Quadrex Corp. 1940 NW 67th Place Gainesville, FL 32606-1649	Bernhardt Warren	(904) 373-6066	FL Radioactive License FL Part B Permit	Liquid scintillation fluids only	Liquid scintillation materials	40,000 ft^3/year 4,500 drums/month Storage: 3,000 gal (tank) plus 1,750 drums	LSF bulking/vial shredding
RAMP Industries 1127 W 46th Avenue Denver, CO 80211	John Lucas	(303) 480-1481	CO Radioactive License CO Part B Permit	D001, F003, F005, F001, F002, and variety of D wastes D002 expected now (see also list in Appendix B)	Liquid scintillation materials, oxidizers, and miscellaneous materials	25,000 ft^3/year 6,000 ft^3/year 5,000 ft^3/year 600 ft^3/year Storage: 750 drums	LSF bulking/vial shredding Neutralization Stabilization Solidification Plus others: Compaction, shredding
Envirocare 215 S State Street Suite 1160 Salt Lake City, UT 84111	Kurt Higgins	(801) 532-1330	UT Radioactive License UT Part B Permit	NARM, source, by-product, SNM[6] (also see list in Appendix B)	Disposal only at present: treatment to be offered in future	550 acres available for low activity- and (future-) RCRA	Disposal Possible future treatment of mixed waste

Table 5.4 Current and potential future commercial industries treating mixed waste							
Company/location	**Contact**	**Telephone**	**Permits**	**Permitted materials**	**Description**	**Capacity[1]**	**Treatment technologies[1]**
SEG[2,3] P.O. Box 2530 1560 Bear Creek Road Oak Ridge, TN 37830	Bud Arrowsmith Jim Harvey	(615) 481-0222	TN Radioactive License Other permits proposed	Radioactive materials only (also see list in Appendix B)	No mixed wastes currently	None	*Future capability for mixed wastes:* Incineration, segregation, stabilization, solidification

[1]Vendor capabilities are based on information provided by the vendors and were not verified.

[2]The following acronyms are used: Diversified Scientific Services, Inc. (DSSI), NSSI/Recovery Services. Inc. (NSSI), and Scientific Ecology Group (SEG).

[3]SEG cannot treat mixed wastes at the present time. They are applying for the necessary Tennessee Part B permits for simple treatment (segregation, stabilization, solidification, etc.) and for incineration of mixed waste.

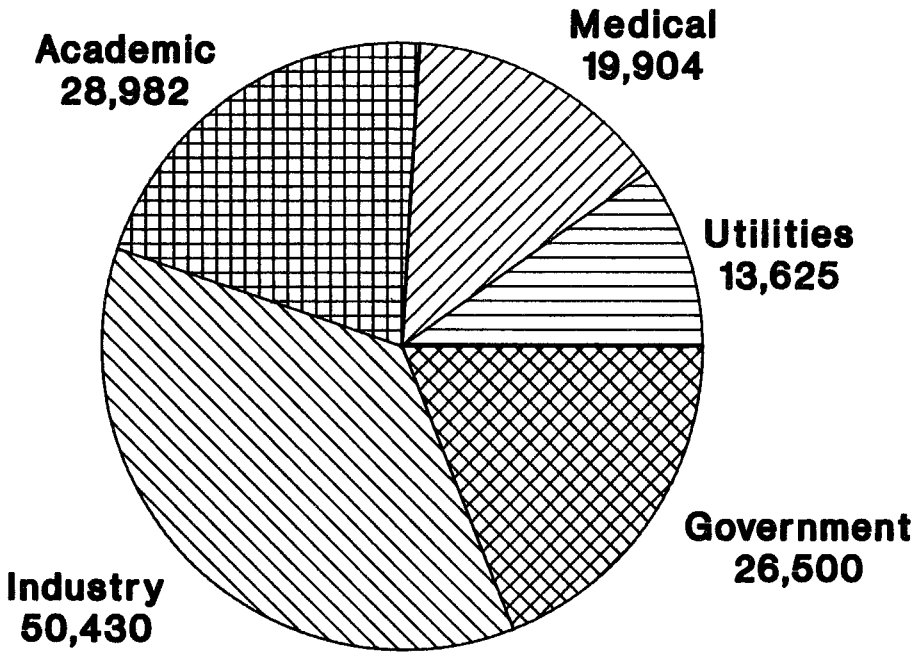
[4]Tennessee lists scintillation liquids as EPA D001 wastes, other states list them as F003 and F005 wastes.

[5]DSSI burns wastes as fuels in a cogeneration boiler.

[6]NARM refers to naturally occurring or accelerator-produced radioactive material. The terms source, by-product, and SNM refer to source, by-product, and special nuclear materials as defined in 10 CFR 40.

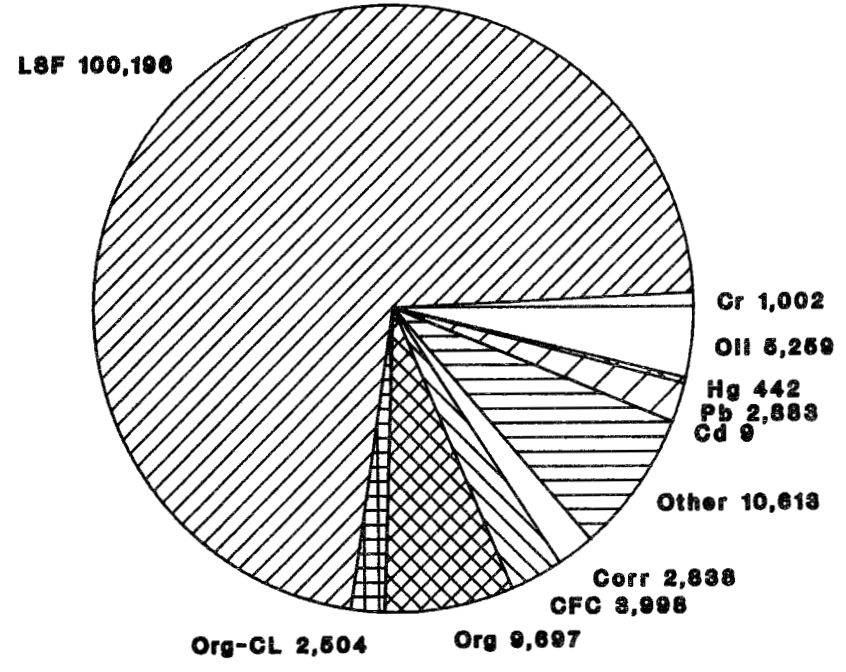
Industries Generating Mixed Waste	Used Liquid Scintillation Cocktails	Organic Chemicals	Lead Wastes	Mercury Wastes	Chromium & Cadmium Wastes	CFC Wastes	Aqueous Corrosive Liquids	Waste Oil
Academic Institutions	•	•	•		•		•	•
Government Institutions	•	•	•		•		•	•
Industry	•	•	•	•	•	•	•	•
Medical Institutions	•	•	•	•			•	
Nuclear Power Plants	•	•	•	•	•	•	•	•

Fig. 4.1. Types of mixed waste streams.



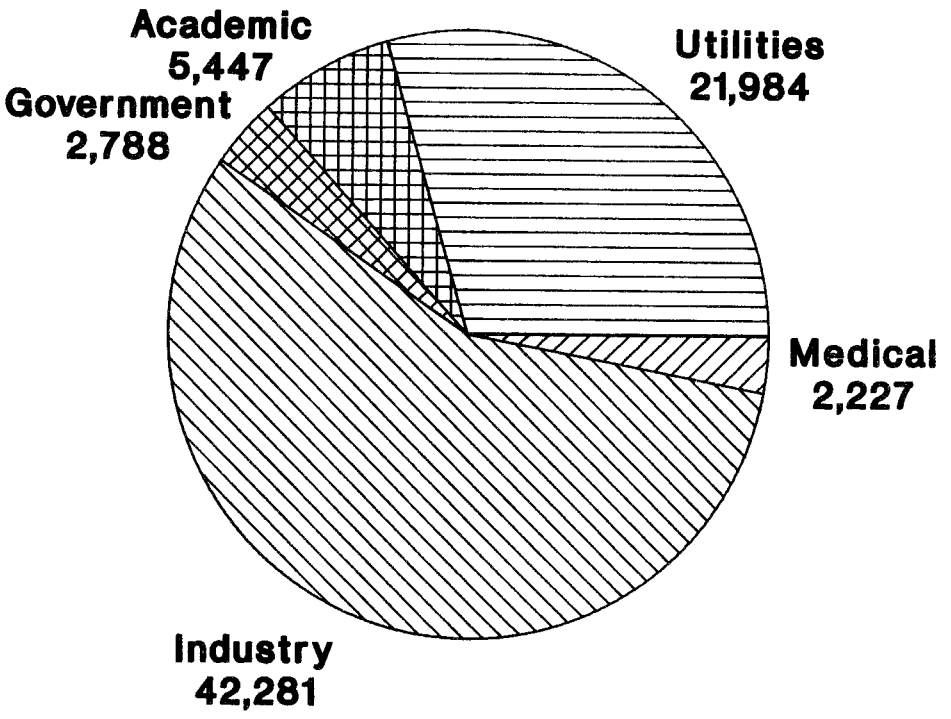
Total: 139,441 ft^3

Fig. 4.2. Mixed waste generation in 1990 by facility category (weighted).



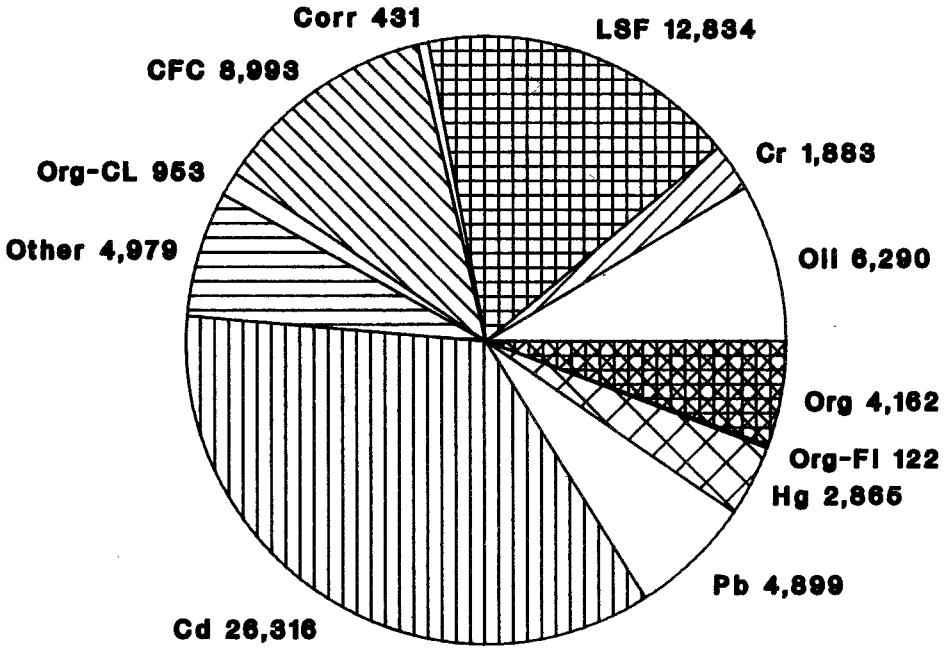
Total: 139,441 ft^3

Fig. 4.3. Mixed waste generation in 1990 by hazardous waste stream (weighted).



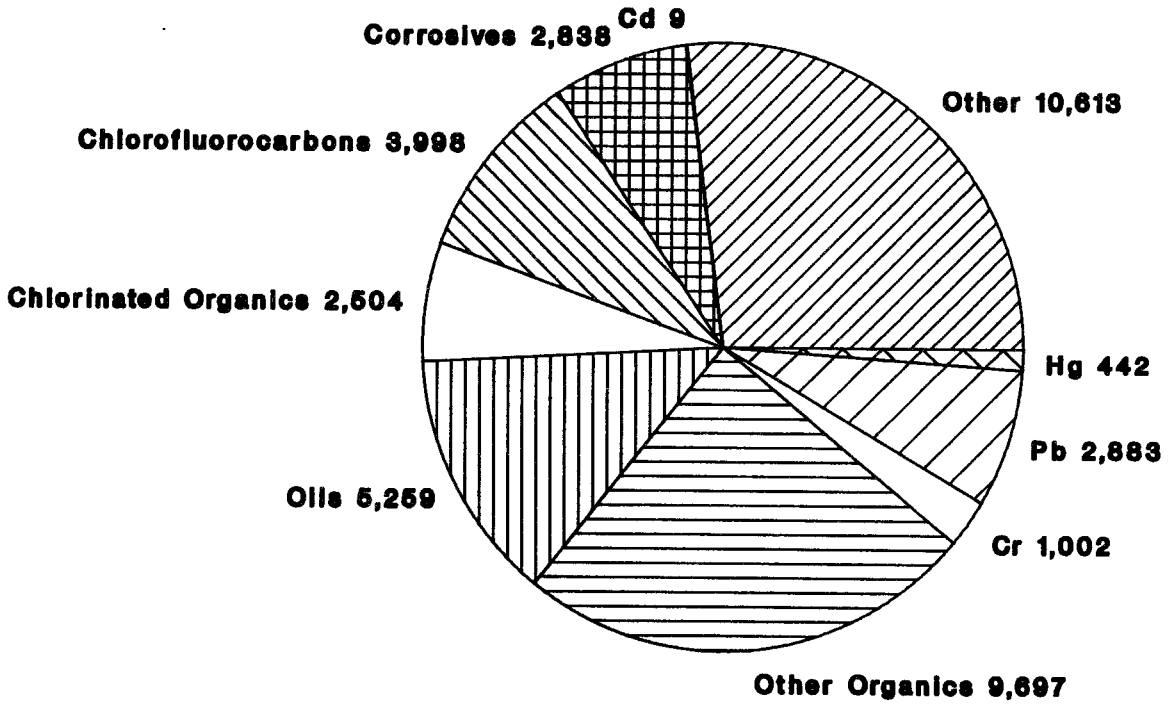
Total: 74,727 ft^3

Fig. 4.4. Mixed waste in storage as of 12/31/90 by facility category (weighted).



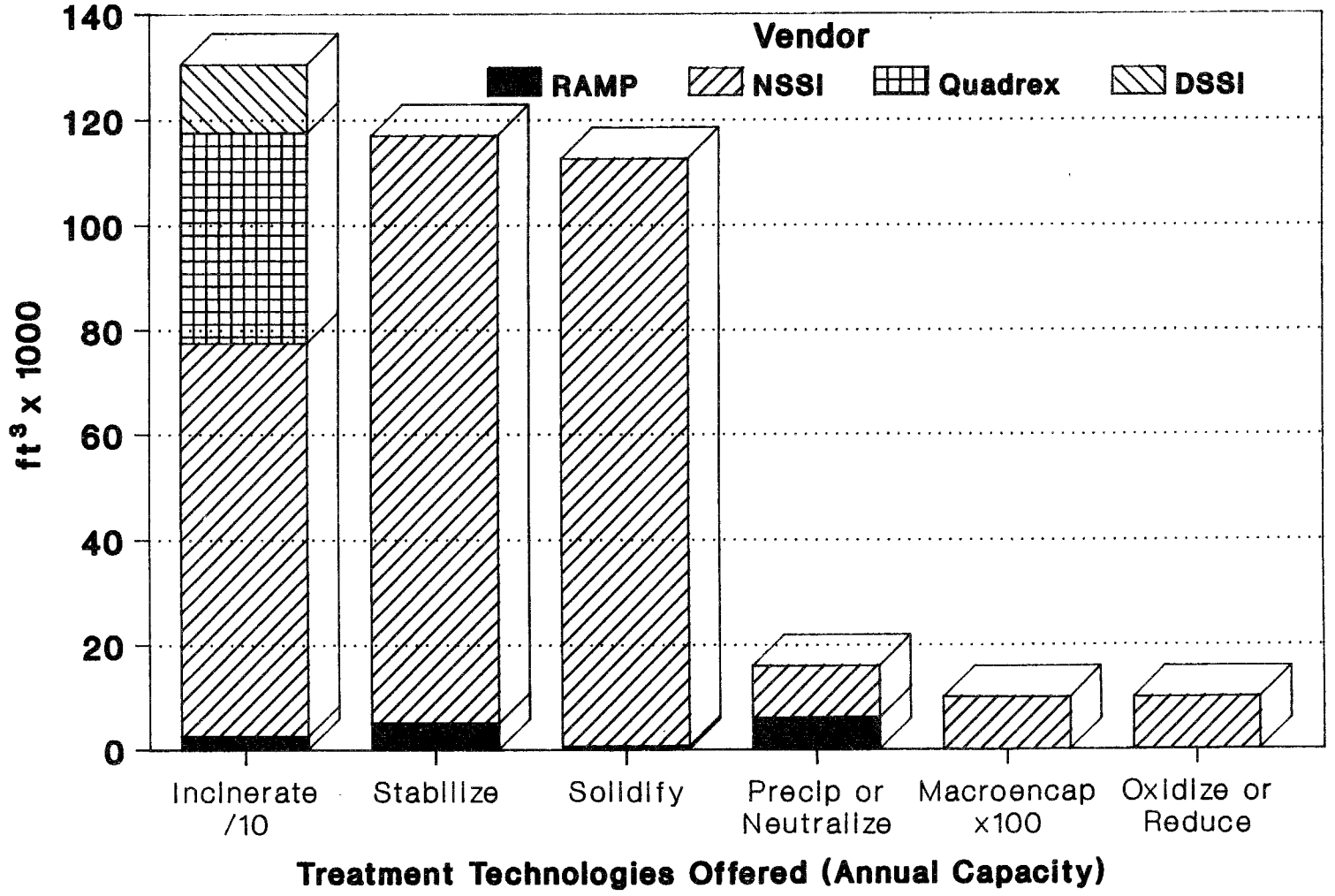
Total: 74,727 ft^3

Fig. 4.5. Mixed waste in storage as of 12/31/90 by hazardous waste stream (weighted).



Total: 39,245 ft^3

Fig. 5.1. Mixed waste generation in 1990 by hazardous waste stream (weighted) without liquid scintillation fluids.



Capacities based on estimates provided by vendors.

Fig. 5.2 Commercial treatment capacity by vendor and treatment technology.

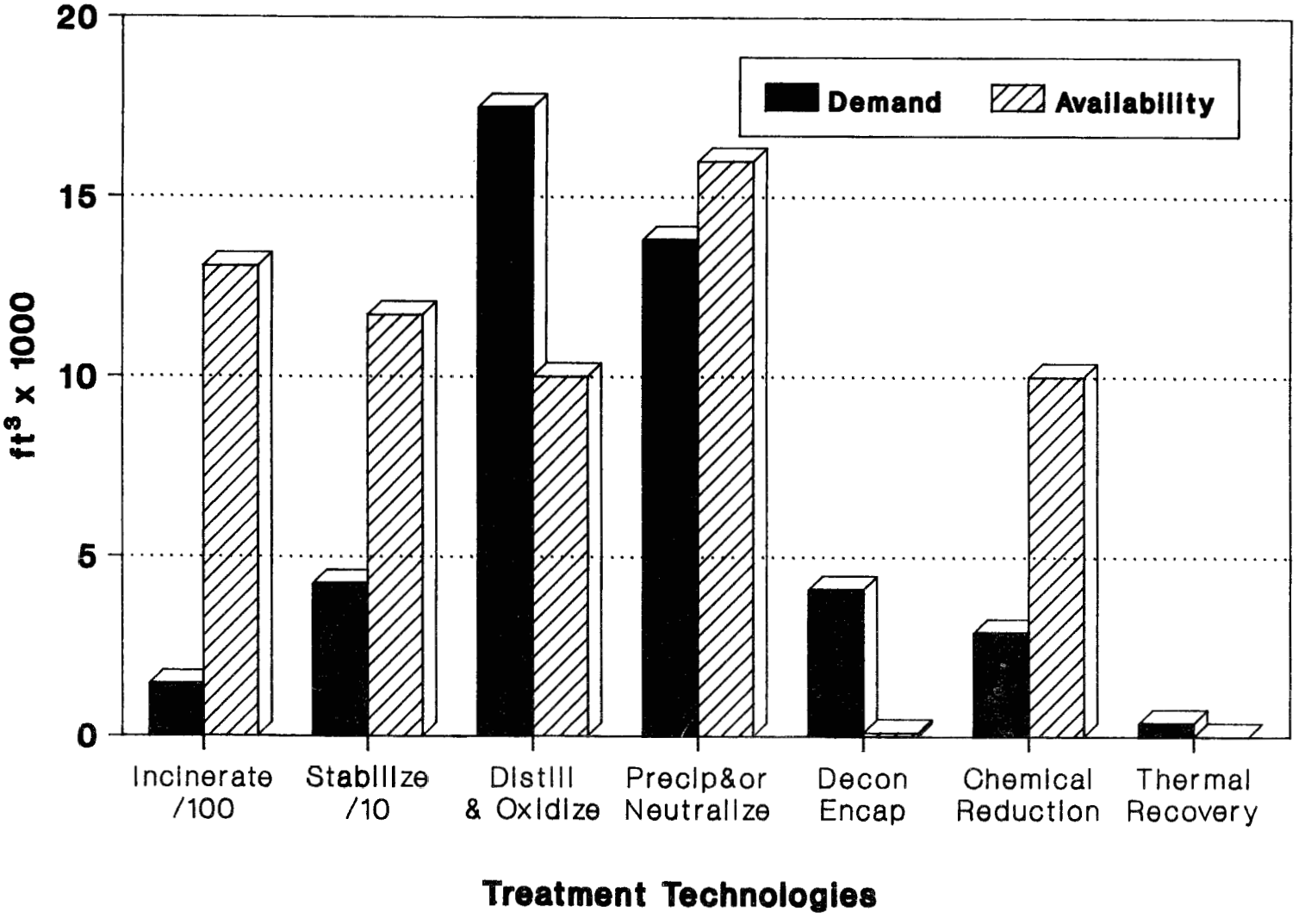


Fig. 5.3 Treatability of mixed waste - availability of services versus demand.

APPENDIX A

STUDY DESIGN SPECIFICATIONS

NATIONAL PROFILE OF MIXED WASTE GENERATORS

SURVEY DESIGN DOCUMENT

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1. Introduction

This document presents the statistical design of a national survey of commercially generated mixed waste. The objective of the survey is to compile a profile, both at the national level and by certain broad classes of establishments, of the volumes, characteristics and treatability of commercially generated and stored mixed waste. Because of the technical nature of the definition of mixed waste, the reader is directed to the "Technical Letter Report for Task Three" developed by Oak Ridge National Laboratory (ORNL) for a full definition. In brief, mixed waste is material which is both Low-Level Radioactive Waste (LLRW) under the Atomic Energy Act and its amendments and a hazardous waste under the Resource Conservation and Recovery Act (RCRA).

The key goals of this document are:

- to characterize the target population;
- to write down the specifics of a sampling plan;
- to describe the details of the data collection plan;
- to describe plans for dealing with survey and sampling errors; and
- to lay the foundation for the estimation process which will follow the data collection process.

The sections which follow will address each of the goals in turn.

2. Characterization of the Target Population

The unit of investigation for this study is defined as an establishment in the United States which has a potential to generate mixed waste. Since an establishment could have mixed waste on its site only if it was licensed by either the NRC or one of the Agreement States to produce, handle or dispose of radioactive waste, we can certainly restrict the target population to such establishments. It is reasonable to suggest also that we further limit the target population to establishments which also have permits or interim status under RCRA. We do not actually employ this limitation because it is possible that an establishment generates mixed waste, for example the emission of a hazardous substance from a piece of equipment on the premises, but is not required to have a permit under RCRA.

Many of the establishments having licenses from the NRC or an Agreement State could not, by the nature of their business, be generators of mixed waste. For example, from the NRC list of approximately 8,000 establishments, only about 1,750 could reasonably generate mixed waste. This group was determined by including only those establishments on the list which have a

Material License Program Code which is, according to the judgment of cognizant technical personnel, associated with an establishment that could possibly generate mixed waste. The Material License Program Codes contain information about the details of the type of radioactive material which the NRC licensee can handle. These codes are included as one of the data items in the data base of NRC licensees which was provided by the NRC. Table 1 contains the specific Material License Program Codes which were included in the definition of the population.

Although an analogous data file to that used for NRC licensed states will not be obtained for the Agreement States, the definition for the target population remains "all establishments on either the NRC or Agreement States lists which, because of the nature of their business, have a chance of generating, either by design or by accident, any mixed waste." We will describe this population as the "potential generators of mixed waste."

Within the population of potential generators of mixed waste, there will be wide variation regarding the likelihood of generating mixed waste. In particular, utilities which are operating nuclear power plants are very likely candidates to generate such wastes because of the volumes of LLRW which are generated on such sites. Therefore it is beneficial to break down the full set of establishments into smaller groups from which to select the sample. Since estimating the volume of mixed waste is the primary goal of the survey, groups which have greater potential to generate substantial volumes will be more likely to be included in the survey. The approach to this segmentation of the sample will be discussed in the next section under "Stratification" of the sample.

3. Sampling Plan

This section will discuss several components of the design of the survey. They include:

- stratification;
- sample size determination;
- sampling frame; and
- sampling procedure.

3.1 Stratification

There are two basic reasons for stratification. The first is to fulfill the requirement for producing estimates within subgroups called estimation cells of the population at a predetermined level of accuracy. This requirement is present in the Mixed Waste Survey as it is required to make accurate estimates for each of the following five types of establishments:

- Utilities
- Medical facilities
- Academic institutions

TABLE 1. Material License Program Codes Included

CODE	DESCRIPTION
01100	Academic Type A Broad
01110	Academic Type B Broad
01120	Academic Type C Broad
02110	Medical Institution Broad
02410	In-Vitro Testing Laboratories
02500	Nuclear Pharmacies
02511	Medical Product Distribution - 32.72
02512	Medical Product Distribution - 32.73
02513	Medical Product Distribution - 32.74
03110	Well Logging Byproduct / SNM Tracer & Sealed Sources
03112	Well Logging Byproduct Only - Tracers Only
03113	Field Flooding Studies
03211	Man and Dist Type Broad A
03212	Man and Dist Type Broad B
03213	Man and Dist Type Broad C
03214	Man and Dist Other
03218	Nuclear Laundry
03220	Leak Test Service Only
03221	Inst Cal Ser Only - Source < 100 Curies
03222	Inst Cal Ser Only - Source > 100 Curies
03223	Leak Test and Inst Cal Ser Only - Source < 100 Curies
03224	Leak Test and Inst Cal Ser Only - Source > 100 Curies
03225	Other Services
03231	Waste Disposal (Burial)
03232	Waste Disposal Service Prepackaged Only
03233	Waste Disposal Service Incineration
03234	Waste Disposal Service Processing and/or Repackaging
03610	R and D Type Broad A
03611	R and D Type Broad B
03612	R and D Type Broad C
03613	R and D Broad - Multisite - Multiregional
03620	R and D Other
11100	Mills
11200	Source Material Other < 150 Kilograms
11220	Source Material Military Munitions Testing
11300	Source Material Other > 150 Kilograms
11400	Uranium Hexafluoride Production Plants
11500	Solutions Testing
11700	Rare Earth Extraction and Processing
11800	Source Material
21130	Hot Cell Operations
21210	Uranium Fuel Processing Plants
21240	Uranium Fuel R&D and Pilot Plants
21310	Critical Mass Material - Universities
21320	Critical Mass Material - Other Than Universities
22110	SNM Plutonium - Unsealed < Critical Mass
22111	SNM U-235 and/or U-233 Unsealed < Critical Mass
22150	SNM Plutonium-Sealed Sources < A Critical Mass
22151	SNM U-235 and/or U-233 Sealed Sources < A Critical Mass
22162	Pacemaker Byproduct and/or SNM Man and Dist
23100	Fresh Fuel At Reactor Sites
25100	Transport-Private Carriage

- Industrial establishments
- Government facilities.

This list requires some clarifications. First, the group defined as "Utilities" includes only those establishments which are nuclear power plants. Other utilities would fall under the more general industrial category. Medical facilities include hospitals, medical laboratories, medical school hospitals and doctors' offices. Government hospitals, such as Veterans Administration hospitals, are classified as Medical establishments rather than being included in the Government category. Academic institutions include all levels of such institutions, but also some academically affiliated research facilities. The Industrial category includes all other private companies and institutions, including research and development institutions.

The second reason to introduce stratification into a survey design is to optimize the accuracy of the estimates ultimately produced. This is accomplished by selecting subgroups within the population which are similar with respect to their characteristics and with respect to the quantities being estimated. We refer to these subgroups as substrata. One example of such a group of establishments is a list which was developed by Oak Ridge National Laboratory (ORNL) from an earlier stage of this study which contains "likely" generators of mixed waste. This list contains many major generators of mixed waste including all utilities holding NRC licenses. Because establishments on this list are considered to represent a large portion of all mixed waste generated in the country, the list will be included in the survey in its entirety as a separate substratum.

Another example of a critical substratum of establishments is the set of all shippers of LLRW who do not already appear on the ORNL list. Because this group of establishments already ships LLRW, they are considered to be much more likely to be generators of mixed waste than other groups in the population. Experts consulted regarding this group also suggested that the amount of mixed waste generated by these establishments will vary widely. This can be interpreted to mean that the standard deviation, a statistical measure of the variability of a set of numbers, for this substratum will be larger than other groups.

Sampling practice dictates that survey resources should be concentrated in those segments of the population in which the variability of the key estimates (total volume of mixed waste in this case) is the highest. Following that practice will accomplish two important goals. First it will result in overall estimates of the total mixed waste which are more accurate. Second it will use the financial resources of the survey project in the most cost effective manner by concentrating the survey among establishments which are most likely to provide the NRC and EPA with useful information.

Exhibit 1 incorporates the two types of stratification discussed above to reveal a breakdown of the population of interest into the primary estimation cells (shown as rows in Exhibit 1) and,

	ORNL List	Shipper's List Excluding ORNL List	Other Potential Mixed Waste Generators				Total
			NRC		Agreement States		
			With EPA Permits	Without EPA Permits	With EPA Permits	Without EPA Permits	
Utilities	67	—	—	—	—		67
Medical	53	369	19	87	40*	170*	738*
Academic	77	207	79	136	160*	270*	929*
Industrial	105	922	167	549	330*	1,100*	3,173*
Government	16	83	5	156	10*	310*	580*
TOTAL	318	1,581	270	928	540*	1,850*	5,487*

* denotes estimate

Exhibit 1. Breakdown of the number of establishments in the population of interest.

within that, by substrata (shown as columns in Exhibit) which are introduced to increase efficiency of estimates. The substratification cells defined in that exhibit are the following:

- **Oak Ridge National Laboratory (ORNL) List.** This substratum is a list of 318 names which was compiled by ORNL. They include all nuclear power plants and other waste generators who, for one reason or another, have been designated likely generators of MW. The list contains both NRC and Agreement State licensees.

- **Shippers List Excluding the ORNL list.** This substratum contains all shippers of LLRW who do not already appear on the ORNL list. Outside of the ORNL list, this group is considered to be the next most likely group to generate mixed waste. This list contains both NRC and Agreement State licensees.

- **Other NRC Potential Mixed Waste Generators.** This substratum is defined in two steps. It starts with the group of establishments having NRC licenses and Material License Program Codes which are considered to be "potential" generators of mixed waste (using the codes in Table 1). The group is further broken down into those with and without EPA Permits to treat, store, dispose or generate hazardous waste.

- **Other Agreement State Potential Mixed Waste Generators.** This substratum is analogous to the NRC category above.

Although there is no list which categorizes these establishments by material license codes (like the NRC list), they are defined as part of the population for completeness. All numbers shown in Exhibit 1 which have an asterisk beside them are estimates and not exact counts as are the other columns in the Exhibit. They were obtained by doubling the numbers shown in the columns marked "NRC" and rounding off to the nearest factor of 10. This method of estimation was used because the total number of Agreement State licensees is approximately 16,000 as compared to 8,000 licensees for the NRC. Thus a factor of 2 was considered reasonable.

The estimates for Other Agreement States Potential Mixed Waste Generators is included in Exhibit 1 to provide a complete picture of the target population. However, after some discussion with NRC technical personnel and the other participants in this research project, it was decided not to include this group in the sampling frame for the survey. Preliminary investigation revealed that information on establishments in Agreement States, in a form analogous to that obtained for NRC establishments, does exist. Further, that information is usually in machine readable form, though with different data formats and having different sets of data fields available. However, to obtain this information it would have required submitting a request, in writing, to each of the 28 Agreement States and allowing approximately 45 days for their responses. It was a management decision, supported by technical input from the project team, that the cost of obtaining and processing this information far outweighed the expected benefit that would accrue from having it.

The latter conclusion was reached based upon the opinion of experts in the nuclear industry that most of the volume of mixed waste would be concentrated in the more easily available lists. It was also suggested that the "Other NRC Potential Mixed Waste Generators," i.e., those not on the ORNL or Shipper's lists, would be similar to the "Other Agreement State Potential Mixed Waste Generators." Therefore, the experts' opinion about the relative importance of the group not available on the ORNL and Shippers lists could be tested with the group of NRC establishments which are included in the sample. If there turns out to be a substantial component of MW found to be generated in the NRC group which is outside of both the ORNL and Shippers Lists, then a model can be built to accommodate that portion of the population on the Agreement State side.

Since no sampling will be done from the two segments of the target population shown in Exhibit 1 under "Other Potential Mixed Waste Generators, Agreement States," they will be excluded from the formal survey process. Therefore these two segments will not be shown in subsequent exhibits. Similarly, the formulation and use of the model, mentioned in the previous paragraph, is considered to be outside the scope of the survey and is not considered further in this design document.

3.2 Sample Size

A sample size determination is made using several key facts about the population and the study goals. Those include the number of units (establishments with potential for generating mixed waste) which are in each of the population strata, estimates for the means and variances of the total volume of mixed waste within each stratum, and the accuracy requirements of the survey.

For the purposes of the sample size estimation, one must formulate a reasonable target for control of sampling error. In surveys, this quantity is often expressed using the concept of relative standard error of the estimate, which is defined as the standard error of the estimate produced by the survey divided by that estimate, and for this survey we based our estimates on a target relative standard error of 10%.

It is useful to explain this concept with an example. If, after collecting the data for this survey, a standard error of 10,000 cubic feet of mixed waste is obtained as associated with an estimate of the total mixed waste generated nationally of 100,000 cubic feet, the relative standard error would be 10%. This figure must be carefully interpreted. Usually, researchers measure the "error" in an estimate by quoting probabilistically based intervals around the estimate which are called confidence intervals. A 95% confidence interval about the above example estimate would be approximately two standard errors, or 20,000 cubic feet of mixed waste.

All error requirements quoted in this document will be stated in terms of relative standard errors. However, they must be transformed into target confidence intervals to be consistent with the stated error requirements of the survey. The overall accuracy requirement set by the sponsors of this project is to be within a factor of two of the actual volume of mixed waste both nationally and within each of the five estimation cells. This requirement results in an asymmetric interval about each estimate which is half the estimate on the lower side and twice the estimate on the upper side. As described above, the relative standard error of 10% of the estimate results in a 95% confidence interval of roughly twice that size or 20% of the estimate. This component of error is that which is due to sampling error (the error introduced because a sample was taken rather than a census). The stated overall accuracy requirement on the lower and upper sides, therefore, leaves room for what is termed "non-sampling" errors. Although one can quantify the size of the sampling error, there is no similar way to quantify the size of the non-sampling error. It is a matter of subjective judgement that the level of the non-sampling error can be contained within the bounds just defined. As will be discussed below, it is generally accepted that sample sizes be defined using methods which quantify sampling error, and that non-sampling error be minimized by using established practices for questionnaire design and testing, and careful attention to all details of survey operations.

	Subgroup Mean	Subgroup Standard Deviation
Utilities	76	140
Medical	78	85
Academic	107	402
Industrial	15	34
Government	15*	34*

* denotes estimate

Exhibit 2. Estimates of Population Means and Standard Deviations in cubic feet.

Consider first the table of means and standard deviations which is shown as Exhibit 2. The two columns of this exhibit contain the means and standard deviations obtained from a small "subgroup" of six States. This information was included in an earlier Technical Letter Report produced by the Oak Ridge National Laboratory for this project. Although the volumes of mixed waste included in this subgroup represent different surveys with different selection criteria, they are the best data we have from which to make mean and standard deviation estimates for the total volume. These numbers are used as a basis for the sample size calculations which are described below. Since the six-State data did not have information about Government establishments, the mean and standard deviation for that group were estimated as being similar to the Industrial sector.

The means and standard deviations for the substrata are assumed to be constant multipliers of the figures shown in Exhibit 2. They differ from the base figures because experts in this field indicate that these groups have very different likelihoods of generating mixed waste. The multipliers of the base mean and standard deviation figures in Exhibit 2 used in producing sample size estimates are the following:

ORNL List	1.00
Shipper's Lists	1.10
Other NRC with EPA Permit	0.40
Other NRC without EPA Permit	0.20.

For example, the estimated means and standard deviations for the Academic substratum are tabulated in Exhibit 3. When the estimates for the mean generated mixed waste for all estimation cells by substrata are combined, a estimate for total mixed waste generated within the sampling frame of the survey is 103,275 cubic feet. A very crude estimate of 100,000 cubic feet of mixed waste was provided by experts in the nuclear industry. Since these figures are roughly consistent, the basic assumptions for the means and

Substratum	Mean	Standard Deviation
ORNL List	107	402
Shippers List	117.7	442.2
Other NRC with EPA Permit	42.8	160.8
Other NRC without EPA Permits	21.4	80.4

Exhibit 3. Mean and standard deviation estimates for mixed waste generated (in units of cubic feet) for the Academic Sector.

standard deviations are considered to be validated.

Using the means and standard deviations just described, we employed Neyman allocation methods to compute a sample size for each of the estimation cells separately. Each estimation cell was handled separately because the error requirements are defined to hold independently for each of these cells. It is clear that meeting the error requirements separately for each of the estimation cells, will ensure the same or better accuracy for estimates related to the combined population.

For completeness, the details of the sample size calculation for the medical estimation cell will be provided here. The sample size calculations for the other estimation cells are similar. Consider the table shown as Exhibit 4. The first four columns in the table correspond to each of the substrata, excluding the "Other Agreement State Potential Generators," within this estimation cell. The rows of the table contain the key information required to perform the sample size computation. The first row contains the total number of establishments in each of the substrata, denoted N_h to indicate population size in substratum h. The second row shows estimates for the mean mixed waste in the substrata derived from Exhibit 2. The next row is derived by multiplying the values in the prior two rows, to produce estimates for the total mixed waste in each substratum, T_h. These estimates are clearly very crude. If the amounts of mixed waste by substratum were known accurately, there would be no need to do a survey. However, for the purposes of sample size estimation and allocation, such estimates are needed. The next row contains an estimate for the standard deviation of the mixed waste in each substratum derived from Exhibit 2 using the adjustment factors for substrata and illustrated in Exhibit 3.

These numbers are combined using standard formulas to produce preliminary estimates of the total sample size required for each estimation cell. Since, the ORNL group had been designated a certainty sector early in this discussion, they are not included in the sample size calculation. This explains the need for the last column of the table. This column contains sums over those columns

	ORNL List*	Shipper's List Excluding ORNL List	Other Potential Mixed Waste Generators		Total	Total for Noncertainty Strata
			NRC			
			With EPA Permit	Without EPA Permit		
Number of Establishments (N_h)	53	369	19	87	528	475
Estimated Mean Mixed Waste in ft^3	78	85.8	31.2	15.6		
Estimated Total Mixed Waste in ft^3 (T_h)	4,134	31,660.2	592.8	1,357.2	37,744.2	33,610.2
Estimated Standard Deviation in ft^3 (S_h)	85	93.5	34	17		
SAMPLE SIZE	53	73	1	3	130	77

* denotes certainty substratum

Exhibit 4. Example of sample size calculation for the Medical estimation cell.

which are not certainty sectors.

The formula used to determine total sample size for the non-certainty cells is the following[1]:

$$n = \frac{(\sum N_h S_h)^2}{V + \sum N_h S_h^2}$$

where V is the estimate for the variance of the total mixed waste for this estimation cell. In this equation, the sum is taken over only those columns in the table which are not certainty sectors, and is found in Exhibit 4 in the very last column of the Exhibit.

[1]Cochran, W. G., Sampling Techniques, Third Edition, John Wiley and Sons, New York, 1977 (equation 5.50 on page 106).

V is determined using a target relative standard error of 10%. As discussed above, the relative standard error is a commonly used quantity for expressing errors in survey estimates. A 95% confidence interval would be approximately plus or minus 20% of the estimate. V is computed as follows:

$$V = (0.10 \times \sum T_h)^2.$$

This latter sum is taken over all columns including the certainty substratum. This is because the accuracy requirement is for the entire estimation cell and not just a subset of it.

The last step of the sample size computation process is to allocate the sample size just computed for the estimation cell as a whole to the individual strata. The certainty sectors are determined already, so the allocation is to the remaining strata. The formula used to allocate, following the Neyman allocation method, is the following:

$$n_h = n \left(\frac{N_h S_h}{\sum N_h S_h}\right).$$

The sum in this equation is over only the non-certainty sectors.

Exhibit 5 contains the results of the preliminary sample size calculation for all of the estimation cells combined. These estimates are preliminary because they are not yet adjusted for expected nonresponse and other constraints that will be discussed below. As Exhibit 5 demonstrates, Neyman allocation tends to concentrate the sample in those segments of the population in which the estimated volume of mixed waste is the highest and, at the same time, the variability in that volume is also the highest.

	ORNL List	Shipper's List Excluding ORNL List	Other Potential Mixed Waste Generators		TOTAL
			NRC		
			With EPA Permit	Without EPA permit	
Utilities	67	-	-	-	67
Medical	53	73	1	3	130
Academic	77	180	25	22	304
Industrial	105	273	18	30	426
Government	16	78	2	27	123
TOTAL	318	604	46	82	1,050

Exhibit 5. Preliminary sample size allocation.

Exhibit 6 contains estimates of the sample sizes for the survey revised to take into consideration the impact of nonresponse on the ultimate set of completed interviews. Nonresponse has two effects. One is that it lowers the number of available cases to be used for estimation, thus lowering the accuracy of the estimates. Second, since those who participate essentially select themselves for participation or not, there could be a subtle bias in the estimates representing the difference between those who choose to respond to the survey versus those who choose not to respond. Since we expect a 75% response rate, the numbers in Exhibit 6 were obtained from Exhibit 5, by multiplying each estimate from non-certainty cells by 1.333, the nonresponse adjustment factor (NRAF). This sample size adjustment can compensate for the fact that the number of cases who respond would be too low, but it cannot compensate for nonresponse bias. We must assume here that the group of responders are similar to the non-responders with respect to volumes of mixed waste generated, so that a nonresponse adjustment is possible. Also, we work to control the impact of non-sampling bias by careful survey operation. This will be discussed further below.

Exhibit 7 contains the final sample size estimates for the survey. These numbers are obtained from Exhibit 6 using the natural constraint that the sample size cannot exceed the total number of establishments in the population from Exhibit 1. This constraint affected the Academic row for the Shipper's column where the NRAF adjusted number of 240 cases was limited to 207. When the remaining 33 cases were allocated to the other two NRC columns, the number of cases in the Academic group having EPA permits was so close to the population total of 79, it was decided to select all such cases for the sample. This increased the sample for that estimation cell from 379 in Exhibit 6 to 407 in Exhibit 7.

	ORNL List	Shipper's List Excluding ORNL List	Other Potential Mixed Waste Generators		TOTAL
			NRC		
			With EPA Permit	Without EPA permit	
Utilities	67	-	-	-	67
Medical	53	97	1	5	155
Academic	77	240	33	29	379
Industrial	105	364	24	40	533
Government	16	104	3	36	159
TOTAL	318	805	61	109	1,293

Exhibit 6. Sample size allocation including adjustment for nonresponse.

Modifications were also made in the Government estimation cell. The NRAF adjusted number appearing in Exhibit 6 of 104 cases for the Shipper's column exceeded the total of 83 cases available. Therefore, all 83 cases were included for sampling in that group, and the 21 other cases were allocated proportionately to the two NRC columns. These combined modifications resulted in a total sample of 1,321 cases, allocated to the various estimation cells and substrata as shown in Exhibit 7.

3.3 Sample size sensitivity

The sample size computations described in the prior section rely upon many assumptions and preliminary estimates. Should these assumptions be shown to be inaccurate, through the experience of the actual survey, the survey accuracy could be different than projected. The sample size estimates presented here were made using information supplied and reviewed by experts in the nuclear industry. The information was considered to be the best available short of actually doing the survey.

Exhibit 8 shows how sample size estimates change as the assumed relative standard errors (RSEs) change. The Exhibit contains sample size allocations for each of the five estimation cells and the total population. Two different assumptions for the RSE, 15% and 20%, are shown. As was mentioned earlier, all of the estimates contained in Exhibits 3 through 7 were obtained assuming a 10% RSE for the survey estimates. Within each of the two alternative accuracy assumptions in Exhibit 8, sample sizes are given for both the base sample estimate (analogous to Exhibit 5) and the final allocation which incorporates the adjustment for non-

	ORNL List	Shipper's List Excluding ORNL List	Other Potential Mixed Waste Generators		TOTAL
			NRC		
			With EPA Permit	Without EPA permit	
Utilities	67*	-	-	-	67
Medical	53*	97	1	4	155
Academic	77*	207*	79*	44	407
Industrial	105*	364	24	40	533
Government	16*	83*	5*	55	159
TOTAL	318	751	109	143	1,321

* denotes a certainty cell (all population units are sampled)

Exhibit 7. Final sample size allocation.

	15% Rel Std Error		20% Rel Std Error	
	Base Sample Size	Adjusted Sample Size	Base Sample Size	Adjusted Sample Size
Utilities	67	67	67	67
Medical	92	105	75	82
Academic	248	304	205	248
Industrial	270	325	205	238
Government	96	123	75	94
TOTAL	773	924	627	729

Exhibit 8. Sample size estimates associated with alternative assumptions for target relative standard errors of estimates.

response (analogous to Exhibit 7). It is clear from Exhibit 8 that sample sizes are effected dramatically by the assumption regarding RSE. The final non-response adjusted sample size estimate from Exhibit 7 is 1,321 as compared to 924 for 15% RSE and 729 for 20% RSE.

The project team decided to use a 10% RSE assumption for this survey for several reasons. First of all, that assumption is conservative. Since any number of the other assumptions made to produce the sample size estimates could be flawed, for example the means and standard deviations shown in Exhibit 2 or the assumed response rate, it is prudent to opt for a larger sample size. Second, an RSE of 10% yields a 95% confidence interval on the survey estimates of plus or minus 20% of those estimates. Since the non-sampling error is controlled only by careful design of the questionnaire and operation of the data collection process, there was a desire to allow sufficient room for non-sampling error to still stay within the management requirement of estimating total mixed waste to within a factor of two. A third reason for this assumption is that it was the judgement of those on the project team that sufficient financial resources were available to solicit the full 1,321 questionnaires, including the provision to do adequate follow-up of respondents.

Exhibit 8 is included in this report to fully document the discussions of the project team in setting the survey design assumptions for the project.

3.4 Sampling frame

The sampling frame is intended to be a complete physical list of the entire target population for this study. In practice, obtaining such lists, either in computer readable form or in a hard copy list, is often difficult; and this particular survey is not an exception to this rule. The definition of the target population is all "potential generators of mixed waste." The word potential was added to the definition to exclude establishments which, because of the nature of their operations, could not generate mixed waste. Work was done with the NRC list to exclude such establishments using Material License Program Codes.

The set of lists that were available for use as all or part of the sampling frame include the following:

- **The Oak Ridge List of Likely MW Generators (the ORNL List).** This list currently shows 318 establishments including all nuclear power plants. The list was formulated during the preliminary work done by ORNL on this project and was augmented slightly during the frame construction phase. It represents a group of establishments which are very likely to generate mixed waste. Since obtaining estimates for total MW generated is the main goal of this survey, this list will be included in the survey in its entirely. The list may be eventually augmented with names from two other compacts to which requests for such information was made. If the names become available at some future date, they will be matched against other substrata and added to the ORNL segment of the population and sampled with certainty.

- **The Shipper's Lists.** These are actually three separate lists of establishments which ship LLRW to one the three sites licensed to handle such waste, one each in the states of South Carolina, Washington, and Nevada. Computer readable lists for sites shipping to South Carolina and Washington were obtained from State authorities. A hard copy list of 31 establishments was obtained from Nevada State authorities and typed manually into a computer file. The three lists were merged and matched via computer to obtain one shipper's list.

- **The NRC Licensee Data Base.** This list contains a complete accounting of all NRC Licensees, and as such is the most complete source for the population of mixed waste generators for NRC states. However, since it is believed that most of the roughly 8,000 licensees would not be potential mixed waste generators, the other lists mentioned above were matched against the NRC list so that a more efficient sampling scheme could be implemented. Also, there is information on the NRC data base (namely, the Material License Program Code) which allowed the 8,000 cases on that file to be reduced to 1,748 potential mixed waste generators. As mentioned earlier, Table 1 of this document contains the complete list of Codes included in

the population. From this point forward, reference to the NRC list will mean the list of 1,748 potential generators.

- **The Agreement State Licensees.** As discussed above, it was not considered cost-effective to obtain and process lists of Agreement State licensees. Therefore, they are not included in the sampling frame for this survey except as they appear on either the ORNL or Shippers lists.

- **Hazardous Waste Data Management System (HWDMS) and Resource Conservation and Recovery Information System (RCRIS).** These data bases contain information about establishments which have permits to treat, store or dispose of hazardous waste under RCRA as well as generators of hazardous waste. The HWDMS is an older data base which is being replaced by RCRIS. At the time frame development was done, only eight states were available in the RCRIS format, the remainder being obtained from HWDMS. In either case, information relating to name, address, phone number, etc. was available. These files were available in computer readable form and, counting generators, included some 300,000 establishments.

In accordance with the sampling stratification described above, the following approach to creating a sampling frame for this survey was implemented. First, all NRC establishments on the ORNL list and the Shipper's Lists were matched against the NRC data base. Agreement State establishments on the ORNL list were crossed with those on the Shipper's Lists. All cases were, therefore, put into one the following unique groups:

(1) the ORNL list;
(2) the Shipper's Lists (excluding any cases on the ORNL list); and
(3) the potential generators on the NRC list which are not on either the shipper's lists or the ORNL list.

More details on the methodology for building the sampling frame will be given in the next section.

3.5 Sampling procedure

Central to the sampling procedure is that each case included in the survey be selected with known probability. Such a sample is called a "probability sample." Without a probability sample, it is not possible to produce estimates of total volumes or other estimates from the survey which can be properly weighted and summed so as to represent the entire population of interest. Therefore, operational activities relating to the sample selection endeavored to preserve the probabilities of selection.

First, the sampling frame was created. As described above, each establishment (unit of sample selection for the survey) was

matched against the other lists to ensure that it appeared in one and only one sector.

The matching and merging proceeded as follows. The first step in this process was to put all files into a consistent computer format, identifying key fields which were in common (name, address, city, state, zip code, and contact person). Next, the three shipper's lists (in two stages) were matched to produce one large shipper's list. This combined shippers list was, then, matched against the ORNL list. When matches were discovered, the two records were collapsed into one record (retaining all information from both sources including which file the record was on). The next phase of the matching used the NRC list (suitably limited to 1,748 establishments as discussed earlier in this document). The cases which did not match to either the ORNL or (combined) shipper's list were assumed to belong to the "Other NRC Potential Mixed Waste Generators" segment of the population. The final matching step compared the NRC group with a combined version of the EPA HWDMS and RCRIS files to place each establishment in the substratum to which it belonged.

All matching was done by name. As this method of matching is not foolproof, it is expected that some duplicates still remain on the frame. The name matching algorithm worked as follows. Two files at a time were matched (as discussed in the previous paragraph). Both files were sorted by state and zip code. Any two records with the same state and zip code which had the first 5 letters of their name in common were shown as a "potential" match. This method produced many more "potential" matches than "actual" matches. The list of "potential" matches was reviewed visually to identify the actual matches. As all statistical work was done using the PC/SAS statistical package, the combining of records was done using a full screen data base editor included in that package.

It should also be mentioned that the allocation of cases in the frame to the five estimation groups (utilities, medical, academic, industrial and Government) could not be done by computer, since no codes indicating which group establishments were in was available on the data bases. Therefore it had to be done by hand using the names on the files. The allocation of establishments was done using the definitions described earlier in this document and reviewed by a second individual at David Cox & Associates. They were, then, sent for review to the technical staff at ORNL. ORNL's comments were incorporated in the final allocation of establishments to estimation cells.

The second major component of sample selection is to select a simple random sample within each of the strata according to the sample size numbers shown in Exhibit 7. In this case the method used was to assign each case in the sampling frame a random number, using the pseudo-random number generator included with the PC/SAS system. Within each of the sampling cells, the cases were sorted by random number and the initial number of cases (matching the number to be sampled from Exhibit 7) was selected as being in the

sample. This is equivalent to selecting a simple random sample within each sampling cell.

4. Data collection methodology

This data collection methodology selected for use in this survey is a mailed out survey with telephone follow-up. The survey forms will be mailed out and respondents will be allowed approximately four weeks to respond before a telephone follow-up will be made.

The follow-up call will consist of two parts. The first part will be a reminder to fill out the survey form. The second part will be an offer either to collect the information over the phone at the time of the call or to schedule a call in the future to collect the information by phone. Should those who promise to send the questionnaire in by mail not fulfill this promise within four weeks of the first call, a second call will be made to collect the data or schedule the collection by phone. Such a protocol has been shown to achieve a response rate that approaches 75% of the cases selected.

5. Assessing and controlling errors

One of the most critical aspects to designing a survey is preparation for errors. The two main categories of error which creep into surveys (whether censuses or samples) are sampling and non-sampling errors. The former refers to the error in estimates which occurs because not all of the cases in the population were used in making the estimate. This is the type of error which can be handled the easiest. Statistical methodology has been developed to the point where such errors are easily quantifiable and estimates of the impact of such errors can be made. In particular for this survey, based upon assumptions of the type used in the section on sample size computation, a sufficient number of sample units has been selected to yield a relative standard error of each estimate of total mixed waste within each estimation cell of 10% of the estimate for the total in that cell. This error requirement corresponds to a 95% confidence interval equal to plus or minus 20% of those estimates.

The other type of error, non-sampling error, is much more difficult to estimate or control. It includes:

1. Nonresponse bias.
2. Frame bias.
3. Response bias (lying, misunderstanding, answering a different question).

The first of these, non-response bias, was discussed briefly above. This type of error exists because not all of the cases selected initially are willing to participate in the survey. The usual approach to handing this error is to carefully arrange the survey

instrument and plan the operations of the survey to minimize the existence of this type of problem; however, additional cases have been included in this sample to accommodate a response rate of 75%. If the survey experiences a response rate lower than 75%, the number of cases in the resulting survey database may be fewer than is required to produce the planned level of accuracy.

A second very important way to improve response relates to how the respondent is contacted and whether he can be convinced that it is in the establishment's best interest to respond. Therefore, trade organizations and other industry groups that could have an influence on response have been contacted to provide supporting letters to be either mailed separately to the sampled establishments or included as an attachment to the main mailout.

Frame bias may result when the sampling frame does not match the target population exactly. The problem in this survey would be when cases which are potential generators of mixed waste are excluded from the frame. In that event, estimates for volumes generated could be either over- or under-estimated. Other frame problems include errors in the information on the lists (e.g., wrong address in a mail survey), duplicate entries on the file, definition of a unit on the frame not matching the definition in the target population (e.g., different uses of the term, "establishment"). The procedures described above for creating the frame were intended to produce the best sampling frame that could be obtained; however, if there are still frame duplicates, it is expected that those which are included in the sample will be found during data collection and noted at that time. During the data analysis step, those for which duplicates were found will be incorporated in an adjustment of the sample weights.

The issue of response bias relates to whether the respondents correctly answer the questions intended. There was some concern that the respondents may not be fully cognizant of the definition of mixed waste and could claim that they do not generate mixed waste (a situation that could exclude them from the survey) when in fact they do.

The impact of response bias is best mitigated by very careful design of the survey instrument. Much care has been taken to ensure that all of the key data items will be included in the survey and that subjective responses are minimized. Also, a survey pretest of approximately 20 establishments which are affiliated with the Appalachian Compact Users of Radioactive Isotopes (ACURI) is in process at this writing. All information relating to the survey instrument obtained from the pretest will be incorporated in the final survey instrument.

6. Estimation

Estimates of total mixed waste generated and other quantities collected in the survey will be produced for each estimation cell. All survey estimators will be weighted using data recording the

probability of selection which will be attached to each respondent's data record at the time of the creation of the sample. If there were no frame problems, nonresponses, or other incomplete responses during the data collection process, the weights that would be used at the analysis phase would be equal to the reciprocal of the probability of selection. However, since the majority of surveys experience some of the problems mentioned, we expect that weight adjustments, mainly for nonresponse, duplicates, and out of scope cases, will be required. Estimates of totals (for example the total mixed waste generated) will take the following form:

$$\hat{Y} = \sum_{i,j,k} Y_{i,j,k} * WGT_{i,j,k} * NRAF_{i,j}$$

where $y_{i,j,k}$ is the response of the kth establishment in the jth stratum (jth column in Exhibit 1) of estimation cell i (the ith row in Exhibit 1). WGT is the initial sampling weight associated with the establishment, and the NRAF (to be explicitly defined below) is the stratum's unit non-response adjustment factor.

The WGT for each stratum is defined as the reciprocal of the probability of selection. This number is the quotient of corresponding cells in Exhibit 1 to those in Exhibit 7 (the population number divided by the sample number). For example, for the Medical estimation cell and the Shippers substratum, the total number of cases in the population (from Exhibit 1) is 369. The sample for that cell (from Exhibit 7) is 97. Therefore, the probability of selection is 97/369 = 0.26287 and the corresponding initial weight, WGT, is 1/0.26287 = 3.8041.

The NRAF is computed as follows:

$$NRAF_{i,j} = \frac{\sum_{viable} WGT_{i,j,k}}{\sum_{usable} WGT_{i,j,k}}$$

where the term "viable" in the formula indicates that the sum should include all units (k) in stratum j and estimation cell i which are in scope for the survey. This would only exclude establishments which were found at the time of data collection to be duplicates, out of business, or otherwise outside of the scope of the survey. The term "usable" refers to all establishments (k) in stratum j and estimation cell i which completed the survey.

Estimates of means or proportions can also be obtained from the survey using standard formulas. A mean would be computed as

follows:

$$\bar{Y} = \frac{\sum_{i,j,k} y_{i,j,k} * WGT_{i,j,k} * NRAF_{i,j}}{\sum_{i,j,k} WGT_{i,j,k} * NRAF_{i,j}}.$$

The proportion of establishments having some characteristic can be computed using the same formula as the mean where the value $y_{i,j,k}$ is interpreted as a 1 or 0 depending on whether the characteristic is present or not.

The final comment regarding estimation relates to estimation of sampling errors. It is generally accepted as good practice in sample surveys to compute sampling errors related to estimates produced. It is planned that such errors will be computed for at least the major estimates of the survey. These include the total volume of mixed waste generated and stored nationally and by major type of establishment. For this survey it is planned to select one of the following three commonly used methods to compute sampling errors:

- balanced half sample replication;
- jackknife; or
- Taylor series approximation.

As a detailed discussion of these methods is beyond the scope of this design document, we provide a reference to the book by Wolter.[1]

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[1]Wolter, K. M. (1985). *Introduction to Variance Estimation*, Springer-Verlag, New York.

APPENDIX B

SURVEY PACKAGE - NATIONAL PROFILE ON MIXED WASTE (INCLUDING MIXED WASTE QUESTIONNAIRE)

OAK RIDGE NATIONAL LABORATORY
OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U.S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831

November 1, 1991

Recipients of the National Profile on Mixed Waste Questionnaire

As described in the following notice, Oak Ridge National Laboratory (ORNL) is participating in a project to develop a national profile on the volumes, characteristics, and treatability of commercially generated low-level radioactive mixed waste. This project is being sponsored by the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA). ORNL is requesting your participation in the development of this profile, by completing the attached questionnaire, as your facility may possibly generate mixed waste. We recognize that a number of facilities that are being asked to participate in this survey may also have participated in recent State or regional surveys. ORNL evaluated many of these surveys as part of our development of the national profile. ORNL determined that while they contain much useful information, results of previous surveys are not adequate to develop a national profile because of differing survey objectives, survey methods, and time frames.

It is important for questionnaire recipients to realize that the data from this profile will be useful to States as they plan and develop low-level radioactive waste disposal capacity as mandated in the Low-Level Radioactive Waste Policy Amendments Act of 1985. This information is not being collected for enforcement purposes by NRC or EPA. In order to make the information available to States in a timely manner, ORNL is requesting that you complete and return the survey form no later than December 2, 1991. Please complete and return the applicable portion of the survey form regardless of whether or not you generate mixed waste.

A self-addressed postcard has been included in the survey package. Your return of this card will indicate that you have received the survey package and have designated an individual to complete the questionnaire. This individual will also serve as a point of contact for any questions ORNL may have about your answers.

We appreciate your support in this important national project. If you have any questions, please feel free to telephone collect:

John Mrochek	(615) 574-6840
Jerry Klein	(615) 576-6823
Andy Francis	(615) 576-8456

Sincerely,

Jerry A. Klein

Jerry A. Klein, Ph.D.
Manager, Nuclear Waste Studies
and Applications

Enclosures

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 7 1991

TO NRC LICENSEES, RCRA STATE PROGRAM DIRECTORS, AND OTHER INTERESTED PARTIES

SUBJECT: ANNOUNCING PLANS FOR MIXED WASTE SURVEY

The purpose of this notice is to inform you of an upcoming survey and to request your support in making this effort a success. The U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) are conducting a voluntary survey to collect information to develop a national profile on the volumes, characteristics, and treatability of commercially generated mixed waste. Mixed waste is waste that contains a radioactive component subject to the Atomic Energy Act (AEA) and a hazardous component subject to the Resource Conservation and Recovery Act (RCRA). The Office of Management and Budget has approved the agencies' plan to survey some 1200 respondents. Since this survey will be limited to approximately 1200 respondents, not every licensee who receives this letter will receive a survey questionnaire. We hope to be in a position to begin the actual survey by September 1991. The results of the survey will be published in the Spring of 1992.

This project was undertaken by the two agencies at the request of the Host State Technical Coordinating Committee (TCC). In May 1990, a letter was sent to NRC Chairman Kenneth M. Carr and EPA Administrator William K. Reilly, by the TCC, requesting the development of a national profile on the volumes and characteristics of commercially generated mixed waste. The stated intent of the national profile should be "... to provide needed information to States and compact officials, private developers, and Federal agencies to assist in the planning and development of treatment and disposal facilities for mixed waste." As a result of this letter and consultations between NRC, EPA, and the Department of Energy (DOE), a contract was awarded to Oak Ridge National Laboratory (ORNL), to initiate work on this study.

This study began with an evaluation of past State, compact, and industry survey data to determine if these data are adequate for compiling a national mixed waste profile. At the conclusion of this initial phase, ORNL found that there was much useful existing information, but that the many different survey objectives and survey methods used, as well as the different timeframes involved in earlier surveys, argue against sole reliance on the existing data. ORNL recommended that a new survey be undertaken, and the two agencies adopted this recommendation.

The survey results are expected to help meet the current information needs of NRC, EPA, States and compact officials, and private developers. This information is expected to: (1) provide States and compacts with information to assist in planning and developing adequate disposal capacity for low-level radioactive waste, including mixed waste, as mandated by the Low-Level Radioactive Waste Policy Amendments Act; (2) provide private developers with a clearer idea of the characteristics and volumes of mixed waste and the technical capability and capacity needed to treat this waste; and (3) provide a reliable national data base on the volumes, characteristics, and treatability of commercial mixed waste. This data may also serve as a basis for possible Federal actions to effectively manage and regulate the treatment and disposal of mixed waste.

The agencies' intent in conducting this survey is to collect accurate and complete information on mixed waste for the reasons outlined above. The data are not being collected for any enforcement purpose. Survey responses will be submitted to and retained by ORNL. Survey results will be provided to NRC and EPA, stripped of any facility identification. Also, any survey results published by NRC or EPA would not identify individual facilities.

States, compact officials, and generators of low-level radioactive waste are asked to support and cooperate with this survey to help ensure that compilation of a national profile will be a meaningful and credible undertaking. The agencies' goal is to achieve at least a 75-percent response rate for this survey. Agreement State cooperation and support are especially needed to ensure that the survey provides a truly national profile. Therefore, NRC and EPA are particularly seeking the aid of Agreement State officials to facilitate making contact with Agreement State licensees. Because of the time-sensitive nature of the project, and our need to compile a national data base, we plan to make direct contact with Agreement State licensees in distributing the survey questionnaire. If this should pose a problem with any Agreement States, please contact Mr. Vandy Miller, Assistant Director for State Agreements Programs, NRC, on 301-492-0326. Any questions about the survey itself should be directed to Chad Glenn, NRC, on 301-492-0567, or Richard LaShier, EPA, on 202-382-2228.

Robert M. Bernero, Director
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission

Sylvia K. Lowrance, Director
Office of Solid Waste
U.S. Environmental Protection Agency

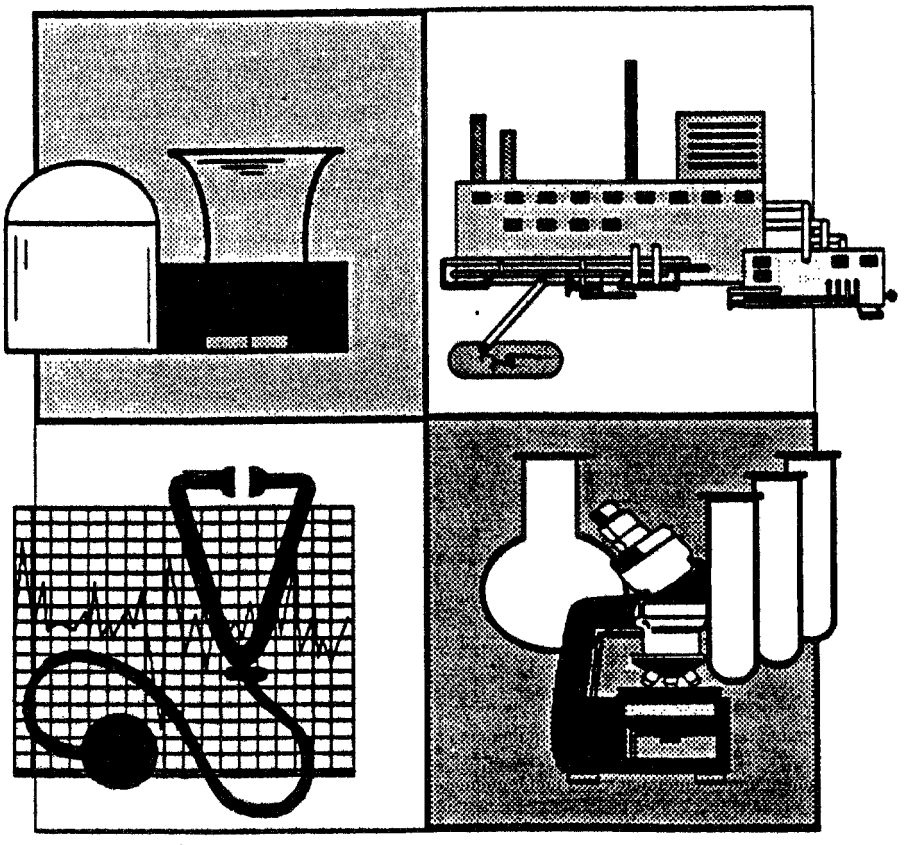
OMB No. 3150-0161 Expiration Date 6/30/92

QUESTIONNAIRE:

NATIONAL PROFILE ON MIXED WASTE

by

Oak Ridge National Laboratory



QUESTIONNAIRE:

NATIONAL PROFILE ON MIXED WASTE

by

Chemical Technology Division

Oak Ridge National Laboratory

Prepared for the
U.S. Nuclear Regulatory Commission
and
U.S. Environmental Protection Agency

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract No. DE-AC05-84-OR21400

QUESTIONNAIRE INSTRUCTIONS

Definitions:

WASTE - For purposes of this study, waste is defined as a material not able to be recycled which must be treated, stored, disposed on-site, or shipped offsite for disposal/storage. This definition is meant to include waste oils or other materials which may be designated as "alternate fuels" and subsequently burned onsite or offsite.

LOW-LEVEL-RADIOACTIVE WASTE - Low-level-radioactive waste (LLRW) is radioactive waste that (a) is not high-level radioactive waste, spent nuclear fuel, or byproduct material as defined in section 11e. (2) of the Atomic Energy Act (i.e. uranium or thorium mill tailings) and (b) the NRC classifies as LLRW consistent with existing law and in accordance with (a).

SOLID WASTE - The Resource Conservation and Recovery Act (RCRA) defines solid waste as "any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities," but does **not** include "source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954...." [RCRA Section 1004(27)]. EPA, NRC, and DOE interpret the exception for source, special nuclear, or byproduct material as referring only to the radionuclide component, and not to the entire waste mixture. [**Low-Level Mixed Waste A RCRA Perspective for NRC Licensees,** EPA/530-SW-90-057].

HAZARDOUS WASTE - A hazardous waste is defined in RCRA as "...a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may..." pose a "substantial present or potential hazard to human health or the environment when improperly...managed." [RCRA Section 1004(5)]. A solid waste is a hazardous waste if it is a "listed" waste or exhibits a hazardous characteristic as outlined in 40 CFR Part 261 Subpart D or C. RCRA-authorized states may declare other materials as hazardous.

MIXED WASTE - For purposes of this project, mixed waste (MW) is defined as "waste that satisfies the definition of LLRW in the LLRW Policy Amendments Act of 1985 (LLRWPAA) and contains hazardous waste that (1) is listed as hazardous waste in Subpart D of 40 CFR Part 261 or (2) causes the LLRW to exhibit any of the hazardous waste characteristics identified in Subpart C of 40 CFR Part 261". In addition, the following are included in the definition of hazardous wastes for the purpose of this study: Oils and sludges, and other wastes classified as hazardous by a RCRA-authorized state.

A. **General Information**

- Facility Information - Name is the facility name as shown on the NRC/Agreement State license or the name as shown on official facility stationary.

- Facility Category - Please select the **single,** best match to your facility's category. If the choice is between two possibilities, select the one most representative of your mixed waste.

- Standard Industrial Classification (SIC) Number - Bureau of Commerce publication

- NRC/Agreement State license number - Self explanatory.

- EPA identification number - Self explanatory. Please note that the size of facility referred to under EPA facility classification is in terms of **total hazardous waste** generated including mixed waste.

- Name and title...- Self explanatory.

B. **Low-Level Radioactive Waste (LLRW)** - Please enter the total, "as-shipped" volume (in cubic feet) of LLRW shipped either to a broker or to a disposal site during 1990 in each of the three radioactive waste classifications and the **Total** volume of LLRW shipped.

Attachment 1 contains a list of 25 potential LLRW streams which, in the case of Biological, Waste Oils, Lead-, Paint-, and Mercury-Containing Wastes are further sub-categorized. If none of these categories fit your waste stream, the last one (No. 226) can be used together with your own description of the stream. A sub-categorized waste stream should be reported as a 4-digit number with the last digit representing the subcategory; all others should be reported as their 3-digit numbers. However, the Waste Stream Numbers which are not sub-categorized may be augmented with a 4th digit to indicate the presence of a hazardous "characteristic" in that waste according to the following rule: 1 - indicating flammable; 2 - indicating reactive; 3 - indicating corrosive; and 4 - indicating toxic (e.g., 2163 would indicate a corrosive mineral extraction waste).

Note that Question B-2 requests information on **generated LLRW** and Question B-3 requests information on **stored LLRW.** Use the defining 3- or 4-digit numbers from Attachment 1 for both questions. Please use the selected waste stream numbers throughout the remainder of the questionnaire for those same generated or stored waste streams. Use the single, most descriptive **name** for that waste stream as shown in Attachment 1 (this is the only place where it should appear in the Questionnaire). Use your best judgement in describing the **Generating Practice** which results in the indicated generated or stored waste; some examples are listed in Questions B-2 and B-3.

Some respondents may immediately categorize a waste as a **mixed waste** without ever classifying it as a LLRW; in such a case, the respondent may wish to bypass Questions B-2, B-3, and Section C, starting immediately with Section D. However, please do

enter a descriptive stream number from Attachment 1. If additional pages are required to complete the requested information, please reproduce additional copies of the needed pages from this Questionnaire.

C. **Hazardous Waste (HW)**

Section C is designed to lead you through the regulations to determine if any of your generated or stored LLRW wastes contain a hazardous material which would cause the waste to be a **mixed waste**. Those facilities located in RCRA-authorized states should review the applicable state regulations for definitions of other hazardous materials declared by their state authorities. Follow the procedure (outlined in Figure C-1) for each **generated** (B-2) and **stored** (B-3) LLRW to identify the generated or stored mixed wastes.

D. **Mixed Waste (MW)**

Complete the information requested for **Generated Mixed Waste** in Questions D-1, D-2, and D-3. Detailed instructions are included with each question.

E. **Stored Mixed Waste**

Complete the information requested for **Stored Mixed Waste** in Questions E-1 and E-2. Detailed instructions are included with each question.

F. **Mixed Waste Minimization**

Please describe, in narrative style, the methods your facility is employing to minimize the generation of mixed waste.

Please remember that the intent of this survey is to gather **complete** and **accurate** information on mixed waste management and is not intended for enforcement purposes. The data reported by you will be used to assist Federal and State regulatory agencies, compact officials, and private developers in making important decisions on mixed waste management and disposal practices for many years. Your cooperation in this survey is greatly appreciated.

Please complete the Questionnaire as accurately as possible within four weeks after receipt and return it in the enclosed envelope to:

OAK RIDGE NATIONAL LABORATORY
ATTN: Dr. J. A. Klein
Nuclear Waste Studies and Applications
P. O. Box 2008, MS-6495
105 Mitchell Road
Oak Ridge, TN 37831-6495

IF YOU HAVE ANY QUESTIONS ABOUT COMPLETING THIS QUESTIONNAIRE, please call collect (615)574-6823, (615)574-6840 or (615)576-8456; M-F, 8:00 AM to 4:30 PM, EST.

MIXED WASTE QUESTIONNAIRE

A. General Information

- Facility Information

Name: _____

Address: _____

_____

_____

_____

- Facility Category

Check **ONE** category which best describes your facility:

1. Nuclear Reactor Facility
   - Boiling Water Reactor (BWR): ____
   - Pressurized Water Reactor (PWR): ____
   - Research & Test Reactors: ____

2. Medical (non-Federal)
   - Hospital
     - <250 beds: ____
     - 250 to 750 beds: ____
     - >750 beds: ____
   - Medical college/hospital: ____
   - Laboratory: ____
   - Research: ____

3. Academic
   - <10,000 students: ____
   - 10,000 - 20,000 students: ____
   - >20,000 students: ____

4. Industrial
   - Manufacturing:
     - <50 employees on site: ____
     - 50 to 200 employees on site: ____
     - >200 employees on site: ____
   - Research and Development: ____
   - Decontamination facility & waste reduction: ____
   - Sealed source/gauge/instrument user: ____
   - Waste broker/processor: ____
   - Nuclear fuel cycle other than power reactors: ____
   - Commercial radiopharmacy: ____

5. Government
   - Federal
     - Hospital: ____
     - Research & Development: ____
     - Military: ____
   - State: ____

   Other (describe): _____

- Standard Industrial Classification (SIC) Number (if known) _____

- NRC/Agreement State license number: _____
- EPA identification number: _____

EPA facility classification

Large quantity generator (>1000 Kg/month): ___
Small quantity generator (100-1000 Kg/month): ___
Conditionally exempt small quantity generator (<100Kg/month): ___
No EPA classification: ___

- Name and title of person completing form and telephone number:

Name: _____

Title: _____

Tel. No.: (___) _____

B. Low-Level Radioactive Waste (LLRW)

B-1. Enter total volume of LLRW (as defined in the Low-Level Radioactive Waste Policy Amendments Act of 1985) **shipped for disposal** during 1990 in cubic feet (one 55-gal drum is equivalent to 7.5 ft^3 and one 30-gal drum is equivalent to 4.0 ft^3), either to a waste broker or directly to a commercial disposal site and list the waste classification (A, B, or C as described in 10 CFR 61.55):

Class A _____ (ft^3)

Class B _____ (ft^3)

Class C _____ (ft^3)

TOTAL LLRW SHIPPED _____ (ft^3)

B-2. List your LLRW streams, **generated** during 1990, by number and the name of the waste (as defined in Attachment 1). Also list practices at your facility that generate this LLRW [e.g. laboratory counting procedures, waste from research or manufacturing, spent reagents, cleaning of laboratory equipment, cleaning of contaminated components, decontamination of lead shielding, lead contaminated during process, backflush of resin filters and changeouts, equipment/tool decontamination, laundering garment waste, pump seal oil, etc.].

B-2 (cont'd).

LLRW STREAM NO. AND NAME		LLRW GENERATING PRACTICE

B-3. List your LLRW, **stored** as of 12/31/90, by number and the name of the waste (as defined in Attachment 1). Under the column headed **LLRW Storage Information**, please indicate the purpose such as Storage (on- or off-site) for Decay, Storage for Accumulation (lowered cost for larger number of drums shipped off-site), Permanent On-Site Storage, Storage for Generator Treatment (volume reduction, incineration, etc.).

STORED LLRW NO. AND NAME		LLRW STORAGE INFORMATION

C. Hazardous Waste (HW)

Hazardous waste is a waste containing components subject to the requirements of the Resource Conservation and Recovery Act (RCRA) of 1976 and its amendments. Mixed waste is a waste with both a hazardous component subject to RCRA and a radioactive component subject to the requirements of the Atomic Energy Act of 1954. You already have determined which of your wastes are radioactive in Section B above. This part of the questionnaire will assist you in determining whether your radioactive wastes also are hazardous (and are, therefore, **mixed wastes**).

Hazardous waste may be solid, semi-liquid, liquid, or gaseous. Your waste is hazardous if (1) the waste is specifically listed in 40 CFR Part 261 Subpart D, or (2) the waste exhibits one of the four characteristics identified in 40 CFR Part 261 Subpart C: ignitability, corrosivity, reactivity, or toxicity.

The following four questions proceed through the HW determination process step-by-step; figure C-1 provides an overview of the 4-question process. **Proceed through the process for each LLRW stream listed in B-2 and for each stored LLRW listed in B-3.** A positive answer to C-2, C-3, or C-4 designates the waste as being hazardous and thus a **mixed waste.**

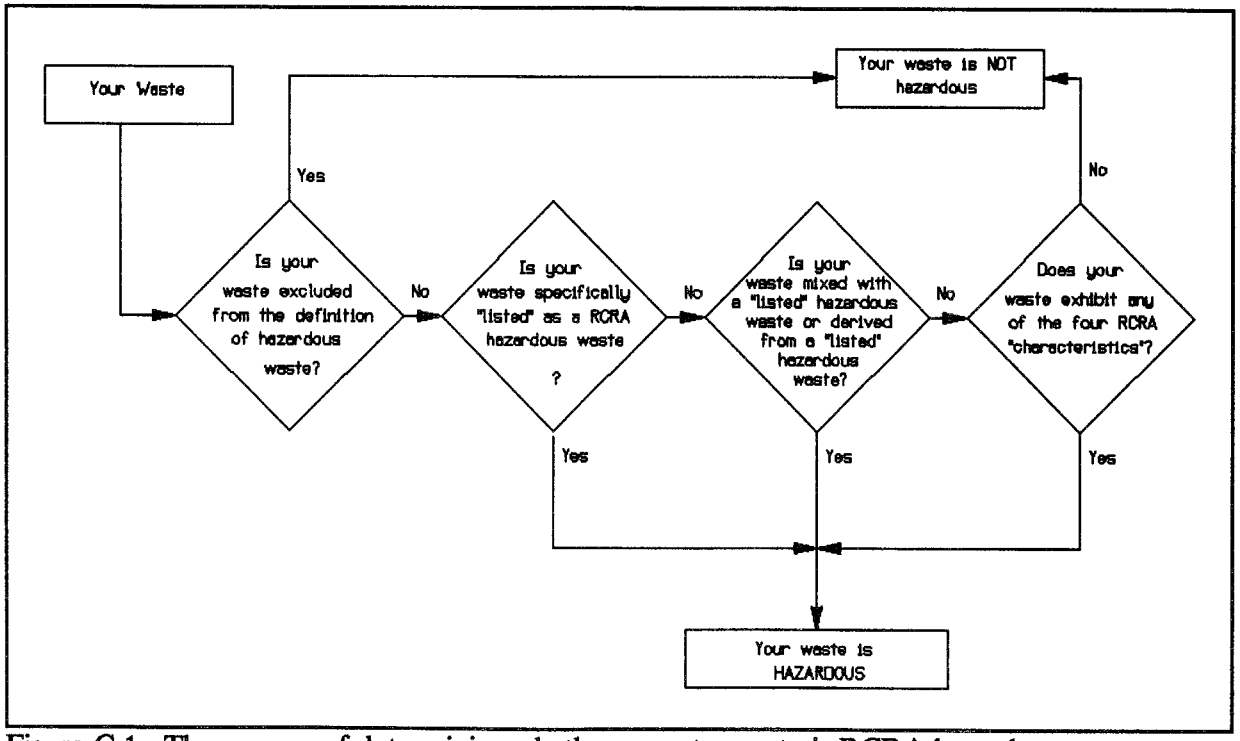


Figure C-1. The process of determining whether or not a waste is RCRA hazardous.

C-1. Is your waste excluded from the definition of hazardous waste?

EXCLUDED MATERIALS (40 CFR 261.4)

Some materials are excluded from the definition of solid waste (and, therefore, cannot be a RCRA hazardous waste):

- Domestic sewage;
- Industrial wastewater discharges regulated under Section 402 of the Clean Water Act;
- Irrigation return flows;
- Source, special nuclear or byproduct material as defined by the Atomic Energy Act[1];
- Materials subjected to in-situ mining techniques which are not removed from the ground as part of the extraction process;
- Pulping liquors that are reclaimed in a pulping liquor recovery furnace and then reused in the pulping process (unless accumulated speculatively);
- Spent sulfuric acid used to produce virgin sulfuric acid (unless accumulated speculatively); and
- Secondary materials that are reclaimed and returned to the original process or processes in which they were generated where they are reused in the production process.

Some solid wastes are excluded from the definition of hazardous waste:

- Household waste;
- Solid waste from agricultural crops and livestock returned to the soils as fertilizer;
- Mining overburden returned to the mine site;
- Ash, slag, and flue gas emission control waste generated primarily from the combustion of fossil fuel;
- Wastes from the exploration, development, or production of crude oil, natural gas, or geothermal energy;
- Chromium wastes from leather tanning and finishing industries, and from titanium oxide production;
- Solid waste from the extraction, beneficiation, and processing of ores and minerals;
- Cement kiln dust waste; and
- Arsenical-treated wood wastes.

Certain hazardous wastes used for treatability studies are exempt from regulation under Subtitle C provided they meet specific conditions (see 40 CFR 261.4 for details).

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[1]For the purposes of determining the applicability of RCRA, "by-product material refers to the actual radionuclides dispersed or suspended in any radioactive waste substance (except special nuclear material) yielded in, or made radioactive by exposure to, the radiation incident to the process of producing or utilizing special nuclear material." This clarification applies only to 42 U.S.C. 2011(e)1 by-product material. According to this clarification, only the actual radionuclides, not the entire waste stream, are considered by-product material; and thus, **RCRA has authority to regulate the hazardous portion of the waste stream.**

_____ YES Your waste is **not** hazardous. Proceed to C-5.

_____ NO Proceed to Question C-2.

C-2. Is your waste specifically "listed" as a RCRA hazardous waste?

LISTED WASTES (40 CFR Part 261 Subpart D)

EPA details all listed hazardous wastes in the following three sections of 40 CFR 261 Subpart D: §261.31 for hazardous waste from non-specific sources; §261.32 for hazardous waste from specific sources; and §261.33 for discarded commercial chemical products, off-specification species, container residues, and spill residues (see Attachment 2, Tables C-1, C-2, C-3, and C-4).

NONSPECIFIC SOURCE LISTED WASTES ("F" WASTES)

There are several broad categories of "F" wastes:

F001 - F005	Spent halogenated and non-halogenated solvents (Note, these listings apply only to solvents that are in fact used for their solubilizing properties, but not to materials used, for example, as carriers. In addition, mixtures or blends of solvents are covered by the listings only if one of the listed solvents comprises at least 10% of the mixture or blend [by volume] before use.)
F006 - F009	Electroplating wastes
F010 - F012	Metal heat treating wastes
F020 - F023	Dioxin wastes
F026 - F028	Dioxin wastes
F019, F024, F025, and F039	Miscellaneous wastes

See Attachment 2, Table C-1, which is organized numerically by the assigned RCRA waste code number.

SPECIFIC SOURCE LISTED WASTES ("K" WASTES)

"K" wastes are organized in the following categories:

Wood preservation	Explosives	Primary lead	Secondary lead
Inorganic pigments	Petroleum refining	Primary zinc	Veterinary pharmaceuticals
Organic pigments	Iron and steel	Primary aluminum	Ink formulation
Inorganic chemicals	Primary copper	Ferroalloys	Coking
Pesticides			

See Attachment 2, Table C-2 which is organized numerically by waste code number.

DISCARDED COMMERCIAL CHEMICAL PRODUCTS, OFF-SPECIFICATION SPECIES, CONTAINER RESIDUES, AND SPILL RESIDUES (EITHER "P" OR "U" WASTES)

Note "P" and "U" lists apply only to chemical substances manufactured or formulated for commercial or manufacturing use, which consist of the commercially pure grade of the chemical, any technical grades of the chemical that are produced or marketed, and all formulations in which the chemical is the sole active ingredient. The lists do not apply to process wastes which contain the listed substances.

See Attachment 2, Tables C-3 and C-4, which are organized numerically by waste code number.

C-2 (cont'd)

_____ YES Your waste is hazardous (begin Section D of the questionnaire).

_____ NO Proceed to Question C-3.

C-3. Is your waste mixed with a "listed" hazardous waste or derived from a "listed" hazardous waste?

MIXTURE AND DERIVED-FROM RULES (40 CFR 261.3)

Mixture Rule

Any solid waste mixed with one or more listed hazardous waste is hazardous. This rule applies regardless of what percentage of the waste mixture is composed of listed hazardous waste **(Note that certain so called "dry wastes" such as solvent- and radionuclide-contaminated rags, may be hazardous wastes via the mixture rule).** The following are exceptions to this rule:

- Wastewater subject to regulation by the Clean Water Act mixed with low concentrations of a listed waste (unless the resultant mixture exhibits one of the characteristics);
- Mixtures of nonhazardous wastes and listed wastes that were listed for exhibiting a characteristic (if the resultant mixture does not exhibit any of the characteristics);
- Mixtures of nonhazardous wastes and characteristic hazardous wastes that no longer exhibit any of the characteristics;
- Certain concentrations of spent solvents and laboratory wastewater that are discharged in low concentrations and do not pose a threat to human health or the environment; and
- *De minimis* losses of discarded commercial chemical products or intermediaries used as raw materials in manufacturing or produced as byproducts.

Derived-From Rule

Any solid waste generated from the management of a listed hazardous waste (including any sludge, spill residue, ash, emission control dust, or leachate, but not including precipitation run-off) **is a hazardous waste.**

_____ YES Your waste is hazardous (begin Section D of the Questionnaire).

_____ NO Proceed to Question C-4.

C-4. Does your waste exhibit any of the four RCRA "characteristics"?

HAZARDOUS CHARACTERISTICS (40 CFR Part 261 Subpart C)

I. **Ignitability** -- A waste is ignitable and is classified as D001 if it meets any of the following criteria:

(1) It is a liquid (except for aqueous solutions containing less than 24 percent alcohol by volume) and has a flash point less than 140° F;
(2) it is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes, and when ignited, burns so vigorously and persistently that it creates a hazard;
(3) it is an ignitable compressed gas, as defined by the Department of Transportation (DOT); or
(4) it is an oxidizer, as defined by DOT.

II. **Corrosivity** -- A waste is corrosive and is classified as D002 if it meets either of the following criteria:

(1) It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, as determined by a pH meter; or
(2) it is a liquid and corrodes steel at a rate greater than 0.25 inches per year at specified conditions.

III. **Reactivity** -- A waste is reactive and is classified as D003 if it meets any of the following critria:

(1) It is normally unstable and readily undergoes violent change without detonating;
(2) it reacts violently with water;
(3) it forms potentially explosive mixtures with water;
(4) when mixed with water, it generates dangerous quantities of toxic fumes, gases, or vapors;
(5) in the case of cyanide- or sulfide-bearing wastes, it generates dangerous quantities of toxic fumes, gases, or vapors when exposed to pH conditions between 2 and 12.5;
(6) it detonates or explodes when subjected to a strong initiating force or heated under confinement;
(7) it readily detonates or decomposes explosively at standard temperature and pressure; or
(8) it is defined by DOT as a forbidden explosive, Class A explosive, or Class B explosive.

IV. **Toxicity** -- A waste exhibits the characteristic of toxicity if, using the Toxicity Characteristic Leaching Procedure (TCLP) as described in 40 CFR Part 261 Appendix II (SW-846, Method 1311), a representative sample of a liquid or the extract of a solid waste contains any of the following constituents at a level equal to or greater than the given value (all values are in mg/L).

EPA Haz.No.		mg/L	EPA Haz.No.		mg/L	EPA Haz.No.		mg/L
D004	Arsenic	5.0	D027	1,4-Dichlorobenzene	7.5	D035	Methyl ethyl ketone	200.0
D005	Barium	100.0	D028	1,2-Dichloroethane	0.5	D036	Nitrobenzene	2.0
D018	Benzene	0.5	D029	1,1-Dichlorethylene	0.7	D037	Pentachlorophenol	100.0
D006	Cadmium	1.0	D030	2,4-Dinitrotoluene	0.1	D038	Pyridine	5.0
D019	Carbon tetrachloride	0.5	D012	Endrin	0.02	D010	Selenium	1.0
D020	Chlordane	0.03	D031	Heptachlor(and epoxide)	0.008	D011	Silver	5.0
D021	Chlorobenzene	100.0	D032	Hexachlorobenzene	0.1	D039	Tetrachloroethylene	0.7
D022	Chloroform	6.0	D033	Hexachloro-1,3-butadiene	0.5	D015	Toxaphene	0.5
D007	Chromium	5.0	D034	Hexachloroethane	3.0	D040	Trichloroethylene	0.5
D023	o-Cresol	200.0	D008	Lead	5.0	D041	2,4,5-Trichlorophenol	400.0
D024	m-Cresol	200.0	D013	Lindane	0.4	D042	2,4,6-Trichlorophenol	2.0
D025	p-Cresol	200.0	D009	Mercury	0.2	D017	2,4,5-TP (Silvex)	1.0
D016	2,4-D	10.0	D014	Methoxychlor	10.0	D043	Vinyl Chloride	0.2

C-4 (cont'd)

_____ YES Your waste is hazardous (begin Section D of this Questionnaire).

_____ NO Your waste is not hazardous (proceed to C-5).

C-5. You have completed Section B of this Questionnaire and defined your LLRW streams and your stored LLRW. You have also completed Section C, which has aided you in determining if any of your LLRW streams or stored wastes also contain hazardous waste; having arrived at this point, you have determined that none of your LLRW contains hazardous waste and thus, you have completed this questionnaire. Please return the Questionnaire to the Oak Ridge National Laboratory in the enclosed envelope. Thank you for your participation in this national survey on the volumes, characteristics, and treatability of commercially generated low-level radioactive mixed waste.

D. Mixed Waste (MW)

D-1. In order for a waste to be regarded as a mixed waste, it must contain radioactive waste and a hazardous waste. The hazardous components of mixed waste typically are organic solvents, metallic lead, mercury, chromate, cadmium wastes, halogenated cleaning/degreasing wastes, aqueous corrosive liquids, or waste oils. For purposes of this study, waste oils and other waste materials which may be designated as "alternate fuels" and burned onsite, are included and should be reported. For each LLRW stream in B-2, identified as containing a hazardous waste in C-2, C-3, or C-4, indicate the **physical form** (aqueous, bulk liquid, adsorbed liquid, uncompacted/compacted solid) and the **basis** for that judgement. Here, one of two responses is requested; a response of T is indicative of **Tested** for hazardous constituent levels exceeding those listed in question C-4 by the TCLP, for its corrosivity by pH measurement (pH less than or equal to 2 or greater than or equal to 12.5), or for its ignitability by measurement of its flash point (less than 60°C/140°F). The second **Basis** response is **PK**, indicating generator reliance on process knowledge to identify a waste as containing a "listed" waste or to determine that the waste would fail a "characteristic" test (Question C-4). Under **Hazardous Component**, the **Name, EPA Hazard Waste No.** (from Attachment 2, Tables C-1, C-2, C-3, C-4 or Question C-4), and the **Source** or origin of the component is requested; some typical names and EPA Hazard Nos. are toluene-F005, xylene-F003, lead-D008, cadmium-D006, chlorofluorocarbons, trichloroethylene, tetrachloroethylene (all three are F001), chromate-D007, etc. Those chemicals which are state-regulated will be indicated by the absence of a EPA Hazard Code No. **Total Volume Generated During 1990** requests the total annual volume (in cubic feet) of the waste stream "**As Generated**" not "as shipped".

WASTE STREAM NO.	PHYSICAL FORM	BASIS (T or PK)	HAZARDOUS COMPONENT NAME AND EPA HAZ. NO.	HAZARDOUS COMPONENT SOURCE	TOTAL VOLUME GENERATED DURING 1990 (ft^3/yr)

D-1 (cont'd)

WASTE STREAM NO.	PHYSICAL FORM	BASIS (T or PK)	HAZARDOUS COMPONENT NAME AND EPA HAZ. NO.	HAZARDOUS COMPONENT SOURCE	TOTAL VOLUME GENERATED DURING 1990 (ft^3/yr)

D-2. For each mixed waste stream listed in D-1, indicate the **Major Radionuclides** (e.g. ^{3}H, ^{14}C, ^{32}P, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{137}Cs, ^{60}Co, etc.) and the radioactive waste **Classification** (A, B, C). List the **Cumulative Activity** in millicuries for each waste in 1990 and indicate whether the waste was **Treated** (onsite/offsite). If the waste was treated, list the **Treatment Type**. Examples of treatments include: Hazardous waste burned for energy or materials recovery, storage for decay, compaction/super compaction, offsite shipment to a treatment facility, encapsulation, stabilization, wastewater treatment for aqueous-based process solutions and facility wastes (neutralization, volume reduction and contaminant removal), and/or other method(s) (please describe). Finally, list the **Volume Treated During 1990** in cubic feet.

WASTE STREAM NO.	MAJ.RADIO NUCLIDES	CLASS (A,B,C)	CUMULATIVE ACTIVITY(mCi)	TREATED (ON/OFF-SITE)	TREATMENT TYPE	VOL. TREATED DURING 1990 (ft^3)

D-3. For each mixed waste shown as being **treated** in D-2, indicate the effect of your current treatment practices. Under **After Treatment**, indicate the new **Volume** (depending on treatment, it may either increase or decrease), the new cumulative **Radioactivity** (if no change use previously listed value), and the effect of the treatment on the **Hazardous Component** in the waste (e.g. neutralization of a corrosive waste to eliminate a hazardous "characteristic", removal of a "listed" hazardous component, or immobilization to eliminate the toxic characteristic). The last column requests the **Volume** of mixed waste remaining after all current treatment techniques have been exhausted and is the waste which, under current conditions, cannot be disposed of.

WASTE STREAM NO.	AFTER TREATMENT			VOL. REQUIRING ULT. DISPOSAL (ft^3/y)
	VOLUME (ft^3)	ACTIVITY (mCi)	EFFECT ON HAZ. COMPONENT	

E. **Stored Mixed Waste**

E-1. We understand the sensitivity on disclosing volume data for stored MW because of the time limitations on such storage after its declaration. However, an ultimate use for the data of this survey is planning for the treatment and ultimate disposal of this type of waste. We reiterate the fact that the data from your facility will **not be associated with the name of your facility in any compiled results provided to NRC or EPA.**

In order for a waste to be regarded as a mixed waste, it must contain radioactive waste and a hazardous waste. The hazardous components of mixed waste typically are organic solvents, metallic lead, mercury, chromate, cadmium wastes, halogenated cleaning/degreasing wastes, aqueous corrosive liquids, or waste oils. For each **stored** LLRW in B-3, identified as containing a hazardous waste in C-2, C-3, or C-4, indicate the **physical form** (aqueous, bulk liquid, adsorbed liquid, uncompacted/compacted solid) and the **basis** for that judgement. Here, one of two responses is requested; a response of T is indicative of **Tested** for hazardous constituent levels exceeding those listed in question C-4 by the TCLP, for its corrosivity by pH measurement (pH less than or equal to 2 or greater than or equal to 12.5), or for its ignitability by measurement of its flash point (less than 60°C/140°F). The second **Basis** response is **PK**, indicating generator reliance on process knowledge to identify a **stored** waste as containing a "listed" waste (Attachment 2, Tables C-1, C-2, C-3, or C-4) or to determine that the

E-1 (cont'd)

waste would fail a "characteristic" test (Question C-4). Under **Hazardous Component**, the **Name, EPA Hazard Waste No.**, and the **Source** or origin of the component is requested; some typical names and EPA Hazard Nos. are lead-D008, cadmium-D006, chlorofluorocarbons, trichloroethylene, tetrachloroethylene (all three are F001), chromate-D007, etc. **Cumulative Amount in Storage** requests that volume, in ft^3, as of December 31, 1990.

WASTE STREAM NO.	PHYSICAL FORM	BASIS (T or PK)	HAZARDOUS COMPONENT NAME AND EPA HAZ. NO.	HAZARDOUS COMPONENT SOURCE	CUMULATIVE AMOUNT IN STORAGE, 12/31/90 (ft^3)

E-2. For each **stored** mixed waste listed in E-1, indicate the **Major Radionuclides** (e.g. ^{3}H, ^{14}C, ^{32}P, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{137}Cs, ^{60}Co, etc.) and the radioactive waste **Classification** (A, B, C). List the **Cumulative Activity** in millicuries for each **stored** waste as of December 31, 1990 and indicate, if possible, a reason for the storage (e.g., storage for decay, accumulation of wastes for future treatment or shipment, unable to treat, ship, or dispose of the waste).

WASTE STREAM NO.	MAJ.RADIO NUCLIDES	CLASS (A,B,C)	CUMULATIVE ACTIVITY(mCi)	REASON FOR STORAGE

E-2 (cont'd)

WASTE STREAM NO.	MAJ.RADIO NUCLIDES	CLASS (A,B,C)	CUMULATIVE ACTIVITY(mCi)	REASON FOR STORAGE

F. **Mixed Waste Minimization**

F-1. What specific actions or procedures are you using to minimize the generation of mixed waste at your facility? (Provide a narrative response in the space below; use additional pages if necessary.)

ATTACHMENT 1

Indicate your radioactive waste streams in Sections B and C and the Tables of Sections D and E by entering their code numbers from the following list. Enter a 3-digit number for those categories which are not sub-categorized, but enter a 4-digit number for a waste stream identity which is sub-categorized, e.g. lead blankets would be identified as 2231 (sub-category 1 under lead). Any of the other Waste Stream Numbers which are not sub-categorized may be augmented to indicate the presence of a hazardous "characteristic" in that waste by the addition of a 4th digit as follows: 1 - indicating flammable; 2 - indicating reactive; 3 - indicating corrosive; and 4 - indicating toxic (e.g. 2173 would indicate a corrosive mineral extraction waste).

Waste Stream No.	Waste Stream Name
201	Biological Waste (Non-infectious) 1. Animal carcasses containing ^{14}C and or tritium 2. Animal carcasses containing radioisotopes other than ^{14}C or tritium 3. Other biological waste
202	Trash and or Solid Waste (not lead) - non-compacted
203	Trash and or Solid Waste (not lead) - compacted
204	Filter Media - Dewatered
205	Filter Media - Solidified
206	Filters, Mechanical
207	Gaseous Sources
208	Incinerator Ash or Residuals
209	Ion Exchange Resins - Dewatered
210	Ion Exchange Resins - Solidified
211	Irradiated Reactor or Pool Components
212	Liquids Aqueous - Absorbed
213	Liquids Aqueous - Solidified
214	Liquids Organic - (Solvents, Chlorinated Solvents, etc.)
215	Liquids Scintillation, containing ^{14}C and/or tritium - (fluids or vials)[1]
216	Liquids Scintillation, containing radioisotopes other than ^{14}C and tritium - (fluids or vials)
217	Mineral Extraction Waste
218	Uranium Sludges
219	Radioactive Sealed Sources, Devices, or Gauges
220	Solidified Evaporator Bottoms/Concentrates/Sump Sludge
221	Vitrified Ash or Resins
222	Waste Oils (Seal Oils from pumps for example) 1. Solvent-contaminated waste oil 2. Waste oil free from solvent contamination
223	Lead-Containing Waste 1. Blankets 2. Sheeting 3. Shielding 4. Batteries 5. Aqueous liquids 6. Organic liquids 7. Lead-contaminated equipment 8. Lead-contaminated trash 9. Other

[1]Scintillation cocktails that contain 0.05 microcuries/g of medium or less of ^{3}H or ^{14}C destined for incineration or disposal shall still be counted as mixed waste for purposes of this survey.

Waste Stream No.	Waste Stream Name
224	Mercury-Containing Waste 1. Elemental mercury 2. Hydraulic oil 3. Solids 4. Liquids 5. Other
225	Paint 1. Water-based 2. Oil-based 3. Epoxy-based 4. Lead-based
226	Other - (Specify)

ATTACHMENT 2

Table C-1. Hazardous wastes from non-specific sources*

Industry and EPA hazardous waste No.	Hazardous waste
Generic:	
F001	The following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F002	The following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethance, ortho-dichlorobenzene, trichlorofluoromethane, and 1,1,2-trichloroethane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents or those listed in F001, F004, or F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F003	The following spent non-halogenated solvents: Xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; all spent solvent mixtures/blends containing, before use, only the above spent non-halogenated solvents; and all spent solvent mixtures/blends containing, before use, one or more of the above non-halogenated solvents and a total of ten percent or more (by volume) of one or more of those solvents listed in F001, F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F004	The following spent non-halogenated solvents: Cresols and cresylic acid, and nitrobenzene; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F005	The following spent non-halogenated solvents: Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, and 2-nitropropane; all spent solvent mixtures/blends containing, before use, a total of ten percent or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, or F004; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F006	Wastewater treatment sludges from electroplating operations except from the following processes: (1) Sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc, and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.
F007	Spent cyanide plating bath solutions from electroplating operations.
F008	Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.

Table C-1. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
F009	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process.
F010	Quenching bath residues from oil baths from metal heat treating operations where cyanides are used in the process.
F011	Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations.
F012	Quenching wastewater treatment sludges from metal heat treating operations where cyanides are used in the process.
F019	Wastewater treatment sludges from the chemical conversion coating of aluminum except from zirconium phosphating in aluminum can washing when such phosphating is an exclusive conversion coating process.
F020	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- or tetrachlorophenol, or of intermediates used to produce their pesticide derivatives. (This listing does not include wastes from the production of Hexachlorophene from highly purified 2,4,5-trichlorophenol.)
F021	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of pentachlorophenol, or of intermediates used to produce its derivatives.
F022	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzenes under alkaline conditions.
F023	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the production or manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tri- and tetrachlorophenos. (This listing does not include wastes from equipment used only for the production or use of Hexachlorophene from highly purified 2,4,5-trichlorophenol.)
F024	Process wastes, including but not limited to, distillation residues, heavy ends, tars, and reactor clean-out wastes, from the production of certain chlorinated aliphatic hydrocarbons by free radical catalyzed processes. These chlorinated aliphatic hydrocarbons are those having carbon chain lengths ranging from one to and including five, with varying amounts and positions of chlorine substitution. (This listing does not include wastewaters, wastewater treatment sludges, spent catalysts, and wastes listed in § 261.31 or § 261.32.)
F025	Condensed light ends, spent filters and filter aids, and spent desiccant wastes from the production of certain chlorinated aliphatic hydrocarbons, by free radical catalyzed processes. These chlorinated aliphatic hydrocarbons are those having carbon chain lengths ranging from one to and including five, with varying amounts and positions of chlorine substitution.

Table C-1. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
F026	Wastes (except wastewater and spent carbon from hydrogen chloride purification) from the production of materials on equipment previously used for the manufacturing use (as a reactant, chemical intermediate, or component in a formulating process) of tetra-, penta-, or hexachlorobenzene under alkaline conditions.
F027	Discarded unused formulations containing tri-, tetra, or pentachlorophenol or discarded unused formulations containing compounds derived from these chlorophenols. (This listing does not include formulations containing Hexachlorophene synthesized from prepurified 2,4,5-trichlorophenol as the sole component.)
F028	Residues resulting from the incineration or thermal treatment of soil contaminated with EPA Hazardous Waste Nos. F020, F021, F022, F023, F026, and F027.
F039	Leachate resulting from the treatment, storage, or disposal of wastes classified by more than one waste code under Subpart D, or from a mixture of wastes classified under Subparts C and D of this part. [Leachate resulting from the management of one or more of the following EPA Hazardous Wastes and no other hazardous wastes retains its hazardous waste code(s): F020, F021, F022, F023, F026, F027, and/or F028.]

*From 40 CFR 261.31.

Table C-2. Hazardous wastes from specific sources*

Industry and EPA hazardous waste No.	Hazardous waste
Wood preservation:	
K001	Bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol.
Inorganic pigments:	
K002	Wastewater treatment sludge from the production of chrome yellow and orange pigments.
K003	Wastewater treatment sludge from the production of molybdate orange pigments.
K004	Wastewater treatment sludge from the production of zinc yellow pigments.
K005	Wastewater treatment sludge from the production of chrome green pigments.
K006	Wastewater treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated).
K007	Wastewater treatment sludge from the production of iron blue pigments.
K008	Oven residue from the production of chrome oxide green pigments.
Organic chemicals:	
K009	Distillation bottoms from the production of acetaldehyde from ethylene.
K010	Distillation side cuts from the production of acetaldehyde from ethylene.
K011	Bottom stream from the wastewater stripper in the production of acrylonitrile.
K013	Bottom stream from the acetonitrile column in the production of acrylonitrile.
K014	Bottoms from the acetonitrile purification column in the production of acrylonitrile.
K015	Still bottoms from the distillation of benzyl chloride.
K016	Heavy ends or distillation residues from the production of carbon tetrachloride.
K017	Heavy ends (still bottoms) from the purification column in the production of epichlorohydrin.
K018	Heavy ends from the fractionation column in ethyl chloride production.
K019	Heavy ends from the distillation of ethylene dichloride in ethylene dichloride production.
K020	Heavy ends from the distillation of vinyl chloride in vinyl chloride monomer production.
K021	Aqueous spent antimony catalyst waste from fluoromethanes production.
K022	Distillation bottom tars from the production of phenol/acetone from cumene.

Table C-2. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
K023	Distillation light ends from the production of phthalic anhydride from naphthalene.
K024	Distillation bottoms from the production of phthalic anhydride from naphthalene.
K025	Distillation bottoms from the production of nitrobenzene by the nitration of benzene.
K026	Stripping still tails from the production of methy ethyl pyridines.
K027	Centrifuge and distillation residues from toluene diisocyanate production.
K028	Spent catalyst from the hydrochlorinator reactor in the production of 1,1,1-trichloroethane.
K029	Waste from the product steam stripper in the production of 1,1,1-trichloroethane.
K030	Column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene.
K083	Distillation bottoms from aniline production.
K085	Distillation or fractionation column bottoms from the production of chlorobenzenes.
K093	Distillation light ends from the production of phthalic anhydride from ortho-xylene.
K094	Distillation bottoms from the production of phthalic anhydride from ortho-xylene.
K095	Distillation bottoms from the production of 1,1,1-trichloroethane.
K096	Heavy ends from the heavy ends column from the production of 1,1,1-trichloroethane.
K103	Process residues from aniline extraction from the production of aniline.
K104	Combined wastewater streams generated from nitrobenzene/aniline production.
K105	Separated aqueous stream from the reactor product washing step in the production of chlorobenzenes.
K107	Column bottoms from product separation from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazines.
K108	Condensed column overheads from product separation and condensed reactor vent gases from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazides.
K109	Spent filter cartridges from product purification from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic acid hydrazides.
K110	Condensed column overheads from intermediate separation from the production of 1,1-dimethylhydrazine (UDMH) from carboxylic and hydrazides.

Table C-2. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
K111	Product washwaters from the production of dinitrotoluene via nitration of toluene.
K112	Reaction by-product water from the drying column in the production of toluenediamine via hydrogenation of dinitrotoluene.
K113	Condensed liquid light ends from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.
K114	Vicinals from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.
K115	Heavy ends from the purification of toluenediamine in the production of toluenediamine via hydrogenation of dinitrotoluene.
K116	Organic condensate from the solvent recovery column in the production of toluene diisocyanate via phosgenation of toluenediamine.
K117	Wastewater from the reactor vent gas scrubber in the production of ethylene dibromide via bromination of ethene.
K118	Spent adsorbent solids from purification of ethylene dibromide in the production of ethylene dibromide via bromination of ethene.
K136	Still bottoms from the purification of ethylene dibromide in the production of ethylene dibromide via bromination of ethene.
Inorganic chemicals:	
K071	Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.
K073	Chlorinated hydrocarbon waste from the purification step of the diaphragm cell process using graphite anodes in chlorine production.
K106	Wastewater treatment sludge from the mercury cell process in chlorine production.
Pesticides:	
K031	By-product salts generated in the production of MSMA and cacodylic acid.
K032	Wastewater treatment sludge from the production of chlordane.
K033	Wastewater and scrub water from the chlorination of cyclopentadiene in the production of chlordane.
K034	Filter solids from the filtration of hexachlorocyclopentadiene in the production of chlordane.
K035	Wastewater treatment sludges generated in the production of creosote.

Table C-2. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
K036	Still bottoms from toluene reclamation distillation in the production of disulfoton.
K037	Wastewater treatment sludges from the production of disulfoton.
K038	Wastewater from the washing and stripping of phorate production.
K039	Filter cake from the filtration of diethylphosphorodithioic acid in the production of phorate.
K040	Wastewater treatment sludge from the production of phorate.
K041	Wastewater treatment sludge from the production of toxaphene.
K042	Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2,4,5-T.
K043	2,6-Dichlorophenol waste from the production of 2,4-D.
K097	Vacuum stripper discharge from the chlordane chlorinator in the production of chlordane.
K098	Untreated process wastewater from the production of toxaphene.
K099	Untreated wastewater from the production of 2,4-D.
K123	Process wastewater (including supernates, filtrates, and washwaters) from the production of ethylenebisdithiocarbamic acid and its salts.
K124	Reactor vent scrubber water from the production of ethylenebisdithiocarbamic acid and its salts.
K125	Filtration, evaporation, and centrifugation solids from the production of ethylenebisdithiocarbamic acid and its salts.
K126	Baghouse dust and floor sweepings in milling and packaging operations from the production or formulation of ethylenebisdithiocarbamic acid and its salts.
K131	Wastewater from the reactor and spent sulfuric acid from the acid dryer from the production of methyl bromide.
K132	Spent absorbent and wastewater separator solids from the production of methyl bromide.
Explosives:	
K044	Wastewater treatment sludges from the manufacturing and processing of explosives.
K045	Spent carbon from the treatment of wastewater containing explosives.
K046	Wastewater treatment sludges from the manufacturing, formulation and loading of lead-based initiating compounds.

Table C-2. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
K047	Pink/red water from TNT operations.
Petroleum refining:	
K048	Dissolved air flotation (DAF) float from the petroleum refining industry.
K049	Slop oil emulsion solids from the petroleum refining industry.
K050	Heat exchanger bundle cleaning sludge from the petroleum refining industry.
K051	API separator sludge from the petroleum refining industry.
K052	Tank bottoms (leaded) from the petroleum refining industry.
Iron and steel:	
K061	Emission control dust/sludge from the primary production of steel in electric furnaces.
K062	Spent pickle liquor generated by steel finishing operations of facilities within the iron and steel industry (SIC Codes 331 and 332).
Primary copper:	
K064	Acid plant blowdown slurry/sludge resulting from the thickening of blowdown slurry from primary copper production.
Primary lead:	
K065	Surface impoundment solids contained in and dredged from surface impoundments at primary lead smelting facilities.
Primary zinc:	
K066	Sludge from treatment of process wastewater and/or acid plant blowdown from primary zinc production.
Primary aluminum:	
K088	Spent potliners from primary aluminum reduction.
Ferroalloys:	
K090	Emission control dust or sludge from ferrochromiumsilicon production.
K091	Emission control dust or sludge from ferrochromium production.
Secondary lead:	
K069	Emission control dust/sludge from secondary lead smelting.

Table C-2. (continued)

Industry and EPA hazardous waste No.	Hazardous waste
K100	Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.
Veterinary pharmaceuticals:	
K084	Wastewater treatment sludges generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
K101	Distillation tar residues from the distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
K102	Residue from the use of activated carbon for decolorization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
Ink formulation:	
K086	Solvent washes and sludges, caustic washes and sludges, or water washes and sludges from cleaning tubs and equipment used in the formulation of ink from pigments, driers, soaps, and stabilizers containing chromium and lead.
Coking:	
K060	Ammonia still lime sludge from coking operations.
K087	Decanter tank tar sludge from coking operations.

*From 40 CFR 261.32.

Table C-3. Discarded commercial chemical products*
(Acute hazardous wastes)

Hazardous Waste No.	Substance
P023	Acetaldehyde, chloro-
P002	Acetamide, N-(aminothioxomethyl)-
P057	Acetamide, 2-fluoro-
P058	Acetic acid, fluoro-, sodium salt
P002	1-Acetyl-2-thiourea
P003	Acrolein
P070	Aldicarb
P004	Aldrin
P005	Allyl alcohol
P006	Aluminum phosphide
P007	5-(Aminomethyl)-3-isoxazolol
P008	4-Aminopyridine
P009	Ammonium picrate
P119	Ammonium vanadate
P099	Argentate(1-), bis(cyano-C)-, potassium
P010	Arsenic acid H_3AsO_4
P012	Arsenic oxide As_2O_3
P011	Arsenic oxide As_2O_5
P011	Arsenic pentoxide
P012	Arsenic trioxide
P038	Arsine, diethyl-
P036	Arsonous dichloride, phenyl-
P054	Aziridine
P067	Aziridine, 2-methyl-
P013	Barium cyanide

Table C-3. (continued)

Hazardous Waste No.	Substance
P024	Benzenamine, 4-chloro-
P077	Benzenamine, 4-nitro-
P028	Benzene, (chloromethyl)-
P042	1,2-Benzenediol, 4-[1-hydroxy-2-(methylamino)ethyl]-
P046	Benzeneethanamine, alpha,alpha-dimethyl-
P014	Benzenethiol
P001	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenylbutyl)-, & salts, when present at concentrations greater than 0.3%
P028	Benzyl chloride
P015	Beryllium
P017	Bromoacetone
P018	Brucine
P045	2-Butanone, 3,3-dimethyl-1-(methylthio)-, O-[(methylamino)carbonyl] oxime
P021	Calcium cyanide
P021	Calcium cyanide $Ca(CN)_2$
P022	Carbon disulfide
P095	Carbonic dichloride
P023	Chloroacetaldehyde
P024	p-Chloroaniline
P026	1-(o-Chlorophenyl)thiourea
P027	3-Chloropropionitrile
P029	Copper cyanide
P029	Copper cyanide $Cu(CN)_2$
P030	Cyanides (soluble cyanide salts), not otherwise specified
P031	Cyanogen
P033	Cyanogen chloride

Table C-3. (continued)

Hazardous Waste No.	Substance
P033	Cyanogen chloride CNCl
P034	2-Cyclohexyl-4, 6-dinitrophenol
P016	Dichloromethyl ether
P036	Dichlorophenylarsine
P037	Dieldrin
P038	Diethylarsine
P041	Diethyl-p-nitrophenyl phosphate
P040	O,O-Diethyl O-pyrazinyl phosphorothioate
P043	Diisopropylfluorophosphate (DFP)
P004	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-, (1alpha,4alpha,4abeta,5alpha,8alpha,8abeta)-
P060	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-, (1alpha,4alpha,4abeta,5beta,8beta,8abeta)-
P037	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2aalpha,3beta,6beta,6aalpha,7beta,7aalpha)-
P051	2,7:3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2abeta,3alpha,6alpha,6abeta,7beta,7aalpha)- & metabolites
P044	Dimethoate
P046	alpha,alpha-Dimethylphenethylamine
P047	4,6-Dinitro-o-cresol & salts
P048	2,4-Dinitrophenol
P020	Dinoseb
P085	Diphosphoramide, octamethyl-
P111	Diphosphoric acid, tetraethyl ester
P039	Disulfoton
P049	Dithiobiuret
P050	Endosulfan
P088	Endothall

Table C-3. (continued)

Hazardous Waste No.	Substance
P051	Endrin
P051	Endrin & metabolites
P042	Epinephrine
P031	Ethanedinitrile
P066	Ethanimidothioic acid, N-[[(methylamino)carbonyl]oxy]-, methyl ester
P101	Ethyl cyanide
P054	Ethyleneimine
P097	Famphur
P056	Fluorine
P057	Fluoroacetamide
P058	Fluoroacetic acid, sodium salt
P065	Fulminic acid, mercury(2+) salt
P059	Heptachlor
P062	Hexaethyl tetraphosphate
P116	Hydrazinecarbothioamide
P068	Hydrazine, methyl-
P063	Hydrocyanic acid
P063	Hydrogen cyanide
P096	Hydrogen phosphide
P060	Isodrin
P007	3(2H)-Isoxazolone, 5-(aminomethyl)-
P092	Mercury, (acetato-O)phenyl-
P065	Mercury fulminate
P082	Methanamine, N-methyl-N-nitroso-
P064	Methane, isocyanato-

Table C-3. (continued)

Hazardous Waste No.	Substance
P016	Methane, oxybis[chloro]-
P112	Methane, tetranitro-
P118	Methanethiol, trichloro-
P050	6,9-Methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-, 3-oxide
P059	4,7-Methano-1H-indene, 1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-
P066	Methomyl
P068	Methyl hydrazine
P064	Methyl isocyanate
P069	2-Methyllactonitrile
P071	Methyl parathion
P072	alpha-Naphthylthiourea
P073	Nickel carbonyl
P073	Nickel carbonyl $Ni(CO)_4$
P074	Nickel cyanide
P074	Nickel cyanide $Ni(CN)_2$
P075	Nicotine & salts
P076	Nitric oxide
P077	p-Nitroaniline
P078	Nitrogen dioxide
P076	Nitrogen oxide NO
P078	Nitrogen oxide NO_2
P081	Nitroglycerine
P082	N-Nitrosodimethylamine
P084	N-Nitrosomethylvinylamine
P085	Octamethylpyrophosphoramide

Table C-3. (continued)

Hazardous Waste No.	Substance
P087	Osmium oxide OsO_4
P087	Osmium tetroxide
P088	7-Oxabicyclo[2,2,1]heptane-2,3-dicarboxylic acid
P089	Parathion
P034	Phenol, 2-cyclohexyl-4,6-dinitro-
P048	Phenol, 2,4-dinitro-
P047	Phenol, 2-methyl-4,6-dinitro-, & salts
P020	Phenol, 2-(1-methylpropyl)-4, 6-dinitro-
P009	Phenol, 2,4,6-trinitro-, ammonium salt
P092	Phenylmercury acetate
P093	Phenylthiourea
P094	Phorate
P095	Phosgene
P096	Phosphine
P041	Phosphoric acid, diethyl 4-nitrophenyl ester
P039	Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio)ethyl] ester
P094	Phosphorodithioic acid, O,O-diethyl S-[(ethylthio)methyl] ester
P044	Phosphorodithioic acid, O,O-dimethyl S-[2-(methylamino)-2-oxoethyl] ester
P043	Phosphorofluoridic acid, bis(1-methylethyl) ester
P089	Phosphorothioic acid, O,O-diethyl O-(4-nitrophenyl) ester
P040	Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester
P097	Phosphorothioic acid, O-[4-[(dimethylamino)sulfonyl]phenyl] O,O-dimethyl ester
P071	Phosphorothioic acid, O,O-dimethyl O-(4-nitrophenyl) ester
P110	Plumbane, tetraethyl-

Table C-3. (continued)

Hazardous Waste No.	Substance
P098	Potassium cyanide
P098	Potassium cyanide KCN
P099	Potassium silver cyanide
P070	Propanal, 2-methyl-2-(methylthio)-O-[(methylamino)carbonyl]oxime
P101	Propanenitrile
P027	Propanenitrile, 3-chloro-
P069	Propanenitrile, 2-hydroxy-2-methyl-
P081	1,2,3-Propanetriol, trinitrate
P017	2-Propanone, 1-bromo-
P102	Propargyl alcohol
P003	2-Propenal
P005	2-Propen-1-ol
P067	1,2-Propylenimine
P102	2-Propyn-1-ol
P008	4-Pyridinamine
P075	Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S), & salts
P114	Selenious acid, dithallium(1+) salt
P103	Selenourea
P104	Silver cyanide
P104	Silver cyanide AgCN
P105	Sodium azide
P106	Sodium cyanide
P106	Sodium cyanide NaCN
P107	Strontium sulfide SrS
P108	Strychnidin-10-one, & salts

Table C-3. (continued)

Hazardous Waste No.	Substance
P018	Strychnidin-10-one, 2,3-dimethoxy-
P108	Strychnine, & salts
P115	Sulfuric acid, dithallium(1+) salt
P109	Tetraethyldithiopyrophosphate
P110	Tetraethyl lead
P111	Tetraethyl pyrophosphate
P112	Tetranitromethane
P062	Tetraphosphoric acid, hexaethyl ester
P113	Thallic oxide
P113	Thallium oxide Tl_2O_3
P114	Thallium(I) selenite
P115	Thallium(I) sulfate
P109	Thiodiphosphoric acid, tetraethyl ester
P045	Thiofanox
P049	Thioimidodicarbonic diamide $[(H_2N)C(S)]_2NH$
P014	Thiophenol
P116	Thiosemicarbazide
P026	Thiourea, (2-chlorophenyl)-
P072	Thiourea, 1-naphthalenyl-
P093	Thiourea, phenyl-
P123	Toxaphene
P118	Trichloromethanethiol
P119	Vanadic acid, ammonium salt
P120	Vanadium oxide V_2O_5
P120	Vanadium pentoxide
P084	Vinylamine, N-methyl-N-nitroso-

Table C-3. (continued)

Hazardous Waste No.	Substance
P001	Warfarin, & salts, when present at concentrations greater than 0.3%
P121	Zinc cyanide
P121	Zinc cyanide $Zn(CN)_2$
P122	Zinc phosphide Zn_3P_2, when present at concentrations greater than 10%

*From 40 CFR 261.33.

Table C-4. Discarded commercial chemical products*
(Toxic wastes)

Hazardous Waste No.	Substance
U001	Acetaldehyde
U034	Acetaldehyde, trichloro-
U187	Acetamide, N-(4-ethoxyphenyl)-
U005	Acetamide, N-9H-fluoren-2-yl-
U240	Acetic acid, (2,4-dichlorophenoxy)-, salts & esters
U112	Acetic acid ethyl ester
U144	Acetic acid, lead(2+) salt
U214	Acetic acid, thallium(1+) salt
See: F027	Acetic acid (2,4,5-trichlorophenoxy)-
U002	Acetone
U003	Acetonitrile
U004	Acetophenone
U005	2-Acetylaminofluorene
U006	Acetyl chloride
U007	Acrylamide
U008	Acrylic acid
U009	Acrylonitrile
U011	Amitrole
U012	Aniline
U136	Arsenic acid, dimethyl-
U014	Auramine
U015	Azaserine
U010	Azirino[2′,3′:3,4]pyrrolo[1,2-a]indole-4,7-dione, 6-amino-8-[[(aminocarbonyl)oxy]methyl]-1,1a,2,8,8a,8b-hexahydro-8a-methoxy-5-methyl-, [1aS-(1aalpha, 8beta,8aalpha,8balpha)]-
U157	Benz[j]aceanthrylene, 1,2-dihydro-3-methyl-

Table C-4. (continued)

Hazardous Waste No.	Substance
U016	Benz[c]acridine
U017	Benzal chloride
U192	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2-propynyl)-
U018	Benz[a]anthracene
U094	Benz[a]anthracene, 7,12-dimethyl-
U012	Benzenamine
U014	Benzenamine, 4,4'-carbonimidoylbis[N,N-dimethyl]-
U049	Benzenamine, 4-chloro-2-methyl-, hydrochloride
U093	Benzenamine, N,N-dimethyl-4-(phenylazo)-
U328	Benzenamine, 2-methyl-
U353	Benzenamine, 4-methyl-
U158	Benzenamine, 4,4'-methylenebis[2-chloro]-
U222	Benzenamine, 2-methyl-, hydrochloride
U181	Benzenamine, 2-methyl-5-nitro-
U019	Benzene
U038	Benzeneacetic acid, 4-chloro-alpha-(4-chlorophenyl)-alpha-hydroxy-, ethyl ester
U030	Benzene, 1-bromo-4-phenoxy-
U035	Benzenebutanoic acid, 4-[bis(2-chloroethyl)amino]-
U037	Benzene, chloro-
U221	Benezenediamine, ar-methyl-
U028	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester
U069	1,2-Benzenedicarboxylic acid, dibutyl ester
U088	1,2-Benzenedicarboxylic acid, diethyl ester
U102	1,2-Benzenedicarboxylic acid, dimethyl ester
U107	1,2-Benzenedicarboxylic acid, dioctyl ester
U070	Benzene, 1,2-dichloro-

Table C-4. (continued)

Hazardous Waste No.	Substance
U071	Benzene, 1,3-dichloro-
U072	Benzene, 1,4-dichloro-
U060	Benzene, 1,1'-(2,2-dichloroethylidene)bis[4-chloro]-
U017	Benzene, (dichloromethyl)-
U223	Benzene, 1,3-diisocyanatomethyl-
U239	Benzene, dimethyl-
U201	1,3-Benzenediol
U127	Benzene, hexachloro-
U056	Benzene, hexahydro-
U220	Benzene, methyl-
U105	Benzene, 1-methyl-2,4-dinitro-
U106	Benzene, 2-methyl-1,3-dinitro-
U055	Benzene, (1-methylethyl)-
U169	Benzene, nitro-
U183	Benzene, pentachloro-
U185	Benzene, pentachloronitro-
U020	Benzenesulfonic acid chloride
U020	Benzenesulfonyl chloride
U207	Benzene, 1,2,4,5-tetrachloro-
U061	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis[4-chloro]-
U247	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis[4-methoxy]-
U023	Benzene, (trichloromethyl)-
U234	Benzene, 1,3,5-trinitro-
U021	Benzidine
U202	1,2-Benzisothiazol-3(2H)-one, 1,1-dioxide, & salts
U203	1,3-Benzodioxole, 5-(2-propenyl)-

Table C-4. (continued)

Hazardous Waste No.	Substance
U141	1,3-Benzodioxole, 5-(1-propenyl)-
U090	1,3-Benzodioxole, 5-propyl-
U064	Benzo[rst]pentaphene
U248	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1-phenyl-butyl)-, & salts, when present at concentrations of 0.3% or less
U022	Benzo[a]pyrene
U197	p-Benzoquinone
U023	Benzotrichloride
U083	2,2'-Bioxirane
U021	[1,1'-Biphenyl]-4,4'-diamine
U073	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-
U091	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethoxy-
U095	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl-
U225	Bromoform
U030	4-Bromophenyl phenyl ether
U128	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-
U172	1-Butanamine, N-butyl-N-nitroso-
U031	1-Butanol
U159	2-Butanone
U160	2-Butanone, peroxide
U053	2-Butenal
U074	2-Butene, 1,4-dichloro-
U143	2-Butenoic acid, 2-methyl-, 7-[[2,3-dihydroxy-2-(1-methoxyethyl)-3-methyl-1-oxobutoxy]methyl]-2,3,5,7a-tetrahydro-1H-pyrrolizin-1-yl ester, [1S-[1alpha(Z),7(2S*),3R*),7aalpha]]-
U031	n-Butyl alcohol
U136	Cacodylic acid

Table C-4. (continued)

Hazardous Waste No.	Substance
U032	Calcium chromate
U238	Carbamic acid, ethyl ester
U178	Carbamic acid, methylnitroso-, ethyl ester
U097	Carbamic chloride, dimethyl-
U114	Carbamodithioic acid, 1,2-ethanediylbis-, salts & esters
U062	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3-dichloro-2-propenyl) ester
U215	Carbonic acid, dithallium(1+) salt
U033	Carbonic difluoride
U156	Carbonochloridic acid, methyl ester
U033	Carbon oxyfluoride
U211	Carbon tetrachloride
U034	Chloral
U035	Chlorambucil
U036	Chlordane, alpha & gamma isomers
U026	Chlornaphazin
U037	Chlorobenzene
U038	Chlorobenzilate
U039	p-Chloro-m-cresol
U042	2-Chloroethyl vinyl ether
U044	Chloroform
U046	Chloromethyl methyl ether
U047	beta-Chloronaphthalene
U048	o-Chlorophenol
U049	4-Chloro-o-toluidine, hydrochloride
U032	Chromic acid H_2CrO_4, calcium salt

Table C-4. (continued)

Hazardous Waste No.	Substance
U050	Chrysene
U051	Creosote
U052	Cresol (Cresylic acid)
U053	Crotonaldehyde
U055	Cumene
U246	Cyanogen bromide (CN)Br
U197	2,5-Cyclohexadiene-1,4-dione
U056	Cyclohexane
U129	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1alpha,2alpha,3beta,4alpha,5alpha,6beta)-
U057	Cyclohexanone
U130	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-
U058	Cyclophosphamide
U240	2,4-D, salts & esters
U059	Daunomycin
U060	DDD
U061	DDT
U062	Diallate
U063	Dibenz[a,h]anthracene
U064	Dibenzo[a,i]pyrene
U066	1,2-Dibromo-3-chloropropane
U069	Dibutyl phthalate
U070	o-Dichlorobenzene
U071	m-Dichlorobenzene
U072	p-Dichlorobenzene
U073	3,3'-Dichlorobenzidine

Table C-4. (continued)

Hazardous Waste No.	Substance
U074	1,4-Dichloro-2-butene
U075	Dichlorodifluoromethane
U078	1,1-Dichloroethylene
U079	1,2-Dichloroethylene
U025	Dichloroethyl ether
U027	Dichloroisopropyl ether
U024	Dichloromethoxy ethane
U081	2,4-Dichlorophenol
U082	2,6-Dichlorophenol
U084	1,3-Dichloropropene
U085	1,2:3,4-Diepoxybutane
U108	1,4-Diethyleneoxide
U028	Diethylhexyl phthalate
U086	N,N'-Diethylhydrazine
U087	O,O-Diethyl S-methyl dithiophosphate
U088	Diethyl phthalate
U089	Diethylstilbesterol
U090	Dihydrosafrole
U091	3,3'-Dimethoxybenzidine
U092	Dimethylamine
U093	p-Dimethylaminoazobenzene
U094	7,12-Dimethylbenz[a]anthracene
U095	3,3'-Dimethylbenzidine
U096	alpha,alpha-Dimethylbenzylhydroperoxide
U097	Dimethylcarbamoyl chloride
U098	1,1-Dimethylhydrazine

Table C-4. (continued)

Hazardous Waste No.	Substance
U099	1,2-Dimethylhydrazine
U101	2,4-Dimethylphenol
U102	Dimethyl phthalate
U103	Dimethyl sulfate
U105	2,4-Dinitrotoluene
U106	2,6-Dinitrotoluene
U107	Di-n-octyl phthalate
U108	1,4-Dioxane
U109	1,2-Diphenylhydrazine
U110	Dipropylamine
U111	Di-n-propylnitrosamine
U041	Epichlorohydrin
U001	Ethanal
U174	Ethanamine, N-ethyl-N-nitroso-
U155	1,2-Ethanediamine, N,N-dimethyl-N′-2-pyridinyl-N′-(2-thienylmethyl)-
U067	Ethane, 1,2-dibromo-
U076	Ethane, 1,1-dichloro-
U077	Ethane, 1,2-dichloro-
U131	Ethane, hexachloro-
U024	Ethane, 1,1′-[methylenebis(oxy)]bis[2-chloro]-
U117	Ethane, 1,1′-oxybis-(l)
U025	Ethane, 1,1′-oxybis[2-chloro]-
U184	Ethane, pentachloro-
U208	Ethane, 1,1,1,2-tetrachloro-
U209	Ethane, 1,1,2,2-tetrachloro-
U218	Ethanethioamide

Table C-4. (continued)

Hazardous Waste No.	Substance
U226	Ethane, 1,1,1-trichloro-
U227	Ethane, 1,1,2-trichloro-
U359	Ethanol, 2-ethoxy-
U173	Ethanol, 2,2'-(nitrosoimino)bis-
U004	Ethanone, 1-phenyl-
U043	Ethene, chloro-
U042	Ethene, (2-chloroethoxy)-
U078	Ethene, 1,1-dichloro-
U079	Ethene, 1,2-dichloro-
U210	Ethene, tetrachloro-
U228	Ethene, trichloro-
U112	Ethyl acetate
U113	Ethyl acrylate
U238	Ethyl carbamate (urethane)
U117	Ethyl ether
U114	Ethylenebisdithiocarbamic acid, salts & esters
U067	Ethylene dibromide
U077	Ethylene dichloride
U359	Ethylene glycol monoethyl ether
U115	Ethylene oxide
U116	Ethylenethiourea
U076	Ethylidene dichloride
U118	Ethyl methacrylate
U119	Ethyl methanesulfonate
U120	Fluoranthene
U122	Formaldehyde

Table C-4. (continued)

Hazardous Waste No.	Substance
U123	Formic acid
U124	Furan
U125	2-Furancarboxaldehyde
U147	2,5-Furandione
U213	Furan, tetrahydro-
U125	Furfural
U124	Furfuran
U206	Glucopyranose, 2-deoxy-2-(3-methyl-3-nitrosoureido)-, D-
U206	D-Glucose, 2-deoxy-2-[[(methylnitrosoamino)-carbonyl]amino]-
U126	Glycidylaldehyde
U163	Guanidine, N-methyl-N′-nitro-N-nitroso-
U127	Hexachlorobenzene
U128	Hexachlorobutadiene
U130	Hexachlorocyclopentadiene
U131	Hexachloroethane
U132	Hexachlorophene
U243	Hexachloropropene
U133	Hydrazine
U086	Hydrazine, 1,2-diethyl-
U098	Hydrazine, 1,1-dimethyl-
U099	Hydrazine, 1,2-dimethyl-
U109	Hydrazine, 1,2-diphenyl-
U134	Hydrofluoric acid
U134	Hydrogen fluoride
U135	Hydrogen sulfide

Table C-4. (continued)

Hazardous Waste No.	Substance
U135	Hydrogen sulfide H_2S
U096	Hydroperoxide, 1-methyl-1-phenylethyl-
U116	2-Imidazolidinethione
U137	Indeno[1,2,3-cd]pyrene
U190	1,3-Isobenzofurandione
U140	Isobutyl alcohol
U141	Isosafrole
U142	Kepone
U143	Lasiocarpine
U144	Lead acetate
U146	Lead, bis(acetato-O)tetrahydroxytri-
U145	Lead phosphate
U146	Lead subacetate
U129	Lindane
U163	MNNG
U147	Maleic anhydride
U148	Maleic hydrazide
U149	Malononitrile
U150	Melphalan
U151	Mercury
U152	Methacrylonitrile
U092	Methanamine, N-methyl-
U029	Methane, bromo-
U045	Methane, chloro-
U046	Methane, chloromethoxy-
U068	Methane, dibromo-

Table C-4. (continued)

Hazardous Waste No.	Substance
U080	Methane, dichloro-
U075	Methane, dichlorodifluoro-
U138	Methane, iodo-
U119	Methanesulfonic acid, ethyl ester
U211	Methane, tetrachloro-
U153	Methanethiol
U225	Methane, tribromo-
U044	Methane, trichloro-
U121	Methane, trichlorofluoro-
U036	4,7-Methano-1H-indene, 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-
U154	Methanol
U155	Methapyrilene
U142	1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one, 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-
U247	Methoxychlor
U154	Methyl alcohol
U029	Methyl bromide
U186	1-Methylbutadiene
U045	Methyl chloride
U156	Methyl chlorocarbonate
U226	Methyl chloroform
U157	3-Methylcholanthrene
U158	4,4'-Methylenebis(2-chloroaniline)
U068	Methylene bromide
U080	Methylene chloride
U159	Methyl ethyl ketone (MEK)
U160	Methyl ethyl ketone peroxide

Table C-4. (continued)

Hazardous Waste No.	Substance
U138	Methyl iodide
U161	Methyl isobutyl ketone
U162	Methyl methacrylate
U161	4-Methyl-2-pentanone
U164	Methylthiouracil
U010	Mitomycin C
U059	5,12-Naphthacenedione, 8-acetyl-10-[(3-amino-2,3,6-trideoxy)-alpha-L-lyxo-hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,8,11-trihydroxy-1-methoxy-, (8S-cis)-
U167	1-Naphthalenamine
U168	2-Naphthalenamine
U026	Naphthalenamine, N,N′-bis(2-chloroethyl)-
U165	Naphthalene
U047	Naphthalene, 2-chloro-
U166	1,4-Naphthalenedione
U236	2,7-Naphthalenedisulfonic acid, 3,3′-[(3,3′-dimethyl[1,1′-biphenyl]-4,4′-diyl)bis(azo)bis[5-amino-4-hydroxy]-, tetrasodium salt
U166	1,4-Naphthoquinone
U167	alpha-Naphthylamine
U168	beta-Naphthylamine
U217	Nitric acid, thallium(1+) salt
U169	Nitrobenzene
U170	p-Nitrophenol
U171	2-Nitropropane
U172	N-Nitrosodi-n-butylamine
U173	N-Nitrosodiethanolamine
U174	N-Nitrosodiethylamine
U176	N-Nitroso-N-ethylurea

Table C-4. (continued)

Hazardous Waste No.	Substance
U177	N-Nitroso-N-methylurea
U178	N-Nitroso-N-methylurethane
U179	N-Nitrosopiperidine
U180	N-Nitrosopyrrolidine
U181	5-Nitro-o-toluidine
U193	1,2-Oxathiolane, 2,2-dioxide
U058	2H-1,3,2-Oxazaphosphorin-2-amine, N,N-bis(2-chloroethyl)tetrahydro-, 2-oxide
U115	Oxirane
U126	Oxiranecarboxyaldehyde
U041	Oxirane, (chloromethyl)-
U182	Paraldehyde
U183	Pentachlorobenzene
U184	Pentachloroethane
U185	Pentachloronitrobenzene (PCNB)
See: F027	Pentachlorophenol
U161	Pentanol, 4-methyl-
U186	1,3-Pentadiene
U187	Phenacetin
U188	Phenol
U048	Phenol, 2-chloro-
U039	Phenol, 4-chloro-3-methyl-
U081	Phenol, 2,4-dichloro-
U082	Phenol, 2,6-dichloro-
U089	Phenol, 4,4'-(1,2-diethyl-1,2-ethenediyl)bis-
U101	Phenol, 2-4-dimethyl-

Table C-4. (continued)

Hazardous Waste No.	Substance
U052	Phenol, methyl-
U132	Phenol, 2,2′-methylenebis[3,4,6-trichloro]-
U170	Phenol, 4-nitro-
See: F027	Phenol, pentachloro-
See: F027	Phenol, 2,3,4,6-tetrachloro-
See: F027	Phenol, 2,4,5-trichloro-
See: F027	Phenol, 2,4,6-trichloro-
U150	L-Phenylalanine, 4-[bis(2-chloroethyl)amino]-
U145	Phosphoric acid, lead(2+) salt (2:3)
U087	Phosphorodithioic acid, O,O-diethyl S-methyl ester
U189	Phosphorus sulfide
U190	Phthalic anhydride
U191	2-Picoline
U179	Piperidine, 1-nitroso-
U192	Pronamide
U194	1-Propanamine
U111	1-Propanamine, N-nitroso-N-propyl-
U110	1-Propanamine, N-propyl-
U066	Propane, 1,2-dibromo-3-chloro-
U083	Propane, 1,2-dichloro-
U149	Propanedinitrile
U171	Propane, 2-nitro-
U027	Propane, 2,2′-oxybis[2-chloro]-

Table C-4. (continued)

Hazardous Waste No.	Substance
U193	1,3-Propane sultone
See: F027	Propanoic acid, 2-(2,4,5-trichlorophenoxy)-
U235	1-Propanol, 2,3-dibromo-, phosphate (3:1)
U140	1-Propanol, 2-methyl-
U002	2-Propanone
U007	2-Propenamide
U084	1-Propene, 1,3-dichloro-
U243	1-Propene, 1,1,2,3,3,3-hexachloro-
U009	2-Propenenitrile
U152	2-Propenenitrile, 2-methyl-
U008	2-Propenoic acid
U113	2-Propenoic acid, ethyl ester
U118	2-Propenoic acid, 2-methyl-, ethyl ester
U162	2-Propenoic acid, 2-methyl-, methyl ester
U194	n-Propylamine
U083	Propylene dichloride
U148	3,6-Pyridazinedione, 1,2-dihydro-
U196	Pyridine
U191	Pyridine, 2-methyl-
U237	2,4-(1H,3H)-Pyrimidinedione, 5-[bis(2-chloroethyl)amino]-
U164	4(1H)-Pyrimidinone, 2,3-dihydro-6-methyl-2-thioxo-
U180	Pyrrolidine, 1-nitroso-
U200	Reserpine
U201	Resorcinol
U202	Saccharin, & salts

Table C-4. (continued)

Hazardous Waste No.	Substance
U203	Safrole
U204	Selenious acid
U204	Selenium dioxide
U205	Selenium sulfide
U205	Selenium sulfide SeS_2
U015	L-Serine, diazoacetate (ester)
See: F027	Silvex (2,4,5-TP)
U206	Streptozotocin
U103	Sulfuric acid, dimethyl ester
U189	Sulfur phosphide
See: F027	2,4,5-T
U207	1,2,4,5-Tetrachlorobenzene
U208	1,1,1,2-Tetrachloroethane
U209	1,1,2,2-Tetrachloroethane
U210	Tetrachloroethylene
See: F027	2,3,4,6-Tetrachlorophenol
U213	Tetrahydrofuran
U214	Thallium(I) acetate
U215	Thallium(I) carbonate
U216	Thallium(I) chloride
U216	Thallium chloride TlCl
U217	Thallium(I) nitrate
U218	Thioacetamide
U153	Thiomethanol

Table C-4. (continued)

Hazardous Waste No.	Substance
U244	Thioperoxydicarbonic diamide $[(H_2N)C(S)]_2S_2$, tetramethyl-
U219	Thiourea
U244	Thiram
U220	Toluene
U221	Toluenediamine
U223	Toluene diisocyanate
U328	o-Toluidine
U353	p-Toluidine
U222	o-Toluidine hydrochloride
U011	1H-1,2,4-Triazol-3-amine
U227	1,1,2-Trichloroethane
U228	Trichloroethylene
U121	Trichloromonofluoromethane
See: F027	2,4,5-Trichlorophenol
See: F027	2,4,6-Trichlorophenol
U234	1,3,5-Trinitrobenzene
U182	1,3,5-Trioxane, 2,4,6-trimethyl-
U235	Tris(2,3-dibromopropyl) phosphate
U236	Trypan blue
U237	Uracil mustard
U176	Urea, N-ethyl-N-nitroso-
U177	Urea, N-methyl-N-nitroso-
U043	Vinyl chloride
U248	Warfarin, & salts, when present at concentrations of 0.3% or less
U239	Xylene

Table C-4. (continued)

Hazardous Waste No.	Substance
U200	Yohimban-16-carboxylic acid, 11,17-dimethoxy-18-[(3,4,5-trimethoxybenzoyl)oxy]-, methyl ester, (3beta,16beta,17alpha,18beta,20alpha)-
U249	Zinc phosphide Zn_3P_2, when present at concentrations of 10% or less

*From 40 CFR 261.33.

APPENDIX C

FIELD STRUCTURE
MIXED WASTE DATABASE

NATIONAL PROFILE ON MIXED WASTE DATA BASE

The data base for the National Profile on Mixed Waste resides in the PC-based FoxPro software. The data from each questionnaire is organized in several relational files. The files are connected by a common identification number to provide integrity of data and allow reports to be generated from all data files. The files are based on the format of the questionnaire, i.e. file FACILITY.DBF contains data found in section A, file LLRW.DBF data found in section B-1, etc. Keeping exact and range data separated while retaining both allows these data to be used in summations and other statistical calculations as described. Mixtures of hazardous chemicals are organized in subfiles and available under the names of the components of the mixtures. Unlimited comment fields provide additional information to clarify data. The descriptions of the files and their fields are as follows.

Subfile Description

FILE ID: FACILITY.DBF

FILE NAME: Mixed Waste facility file (Section A of the questionnaire)

DESCRIPTION: This file organizes identification information and includes the name and address of the facility returning the questionnaire, the name and title of the individual completing the questionnaire along with numbers identifying the facility.

FILE ID: LLRW.DBF

FILE NAME: Low-Level radioactive waste file (Section B-1 and F of the questionnaire)

DESCRIPTION: This file contains information on the total volume of LLRW shipped for disposal during the survey year by the facility. It also contains any information given on specific actions or procedures taken to minimize the generation of mixed waste at the facility.

FILE ID: LLRW_GS.DBF

FILE NAME: LLRW Generating and Storage file (Section B-2, B-3, C-1, C-2, C-3, C-4 of the questionnaire)

DESCRIPTION: This file contains information on the type of Low-Level Radioactive Waste generated and/or stored at the facility. It also includes information on LLRW generating practices and storage; states when the LLRW is considered hazardous.

FILE ID: MIX_WAST.DBF

FILE NAME: Mixed Waste file (Section D-1 of the questionnaire)

DESCRIPTION: This file contains information on each LLRW stream which is considered hazardous. Information is given on the waste stream number, physical form, basis for documenting the information, hazardous component, source, and total volume of the LLRW stream generated.

Subfile Description

FILE ID: TREATMEN.DBF

FILE NAME: Mixed Waste treatment file (Section D-2 of the questionnaire)

DESCRIPTION: This file contains information on each LLRW stream listed in the mixed waste file. It includes the major radionuclides, the RAD waste classification, the cumulative activity, treatment site, type of treatment, and the volume treated during the year.

FILE ID: TREA_WAS.DBF

FILE NAME: Treated Mixed Waste file (Section D-3 of the questionnaire)

DESCRIPTION: This file contains information on the results of the treatment of each LLRW stream listed in the mixed waste file. It includes the after treatment volume, activity, and effect on the hazardous component, and the volume of the LLRW stream requiring ultimate disposal.

FILE ID: STOR_WAS.DBF

FILE NAME: Stored Mixed Waste file (Section E-1 of the questionnaire)

DESCRIPTION: This file contains information on stored mixed waste streams. Information includes the physical form and the basis for that judgement, the hazardous component and its source, and the cumulative amount in storage at the end of the reporting year.

FILE ID: RADIOACT.DBF

FILE NAME: Radioactivity of stored Mixed Waste file (Section E-2 of the questionnaire)

DESCRIPTION: This file contains information on the major radionuclides in the stored mixed waste. It includes the major radionuclides, RAD waste classification, cumulative activity, and reason for storage.

Data Field Descriptions

FILE ID: FACILITY.DBF

FILE NAME: Mixed Waste facility file (Section A of the questionnaire)

DESCRIPTION: This file organizes identification information and includes the name and address of the facility returning the questionnaire, the name and title of the individual completing the questionnaire along with numbers identifying the facility.

FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	An assigned identifier to unify the parts of the questionnaire. The first position identifies the type of facility, the second a source list, and the next four the sequence. (See Attachment 1)
FACILITY	Name of facility	Name of university, company, or plant where waste is generated or stored.
ADDRESS	Address of facility	Mailing address of facility.
CITY	City of facility	City of facility location.
STATE	State of facility	Two letter abbreviation of state location.
ZIP	Zip code	U.S. zip code, 5 or 9 digit.
FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government, entered as a code. (See Attachment 2)
SICNUM	Standard Industrial Classification Number	
NRCSTATE	NRC/Agreement State license #	
EPAIDNO	EPA identification number	
EPACLASS	EPA facility classification	Rated large, small, or conditionally exempt small quantity generator, entered as a code. (See Attachment 3)
NAME	Name	Name of person completing form.

TITLE	Title	Title of person completing form.
PHONENO	Telephone number	Telephone number of person completing form.
YEAR	Year of questionnaire	The year (2 digits) for which data were reported.
COMMENT	Comment	Field for information found in the first two pages of the questionnaire not fitting one of the above fields.

FILE ID: LLRW.DBF

FILE NAME: Low-level radioactive waste (LLRW) file (Section B-1 and F of the questionnaire)

DESCRIPTION:		This file contains information on the total volume of LLRW shipped for disposal during the survey year by the facility. It also contains any information given on specific actions or procedures taken to minimize the generation of mixed waste at the facility.
FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	Original assigned identifier.
FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government, entered as a code (See Attachment 2).
STATE	State of facility	Two letter abbreviation of state location.
EPACLASS	EPA facility classification	Rated large, small, or conditionally exempt small quantity generator, entered as a code. (See Attachment 3)
LLRWCLA	LLRW Class A	Volume of Low-Level Radioactive Waste Class A shipped for disposal during the year, reported in cubic feet/year.
LLRWCLB	LLRW Class B	Volume of Low-Level Radioactive Waste Class B shipped for disposal during the year, reported in cubic feet/year.
LLRWCLC	LLRW Class C	Volume of Low-Level Radioactive Waste Class C shipped for disposal during the year, reported in cubic

		feet/year.
LLRWTOTL	Total LLRW Shipped	Total volume of Low-Level Radioactive Waste shipped for disposal during the year, reported in cubic feet/year.
YEAR	Year of questionnaire	The year (2 digits) for which data were reported.
COMMENT	Comment	Field for information found in the low-level radioactive waste section of the questionnaire not fitting one of the above fields.
MWMINIM	Mixed waste minimization	Specific action or procedures used to minimize the generation of mixed waste at the facility. (See section F-1 of the questionnaire)

FILE ID: LLRW_GS.DBF

FILE NAME: **LLRW Generating and Storage file (Section B-2, B-3, C-1, C-2, C-3, C-4 of the questionnaire)**

DESCRIPTION: This file contains information on the type of Low-Level Radioactive Waste generated and/or stored at the facility. It also includes information on LLRW generating practices and storage; states when the LLRW is considered hazardous.

FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	Original assigned identifier.
FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government entered as a code. (See Attachment 2)
COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the record number for a common ID number questionnaire. Numbers are G01, G02, etc. for generated waste information and S01, S02, etc. for stored waste information.
LLRWCODE	LLRW waste stream code	A number from Attachment 1 of the questionnaire identifying the LLRW waste stream being generated.

LLRWNAME	LLRW waste stream name	A name from Attachment 1 of the questionnaire identifying the LLRW waste stream being generated.
GENOSTOR	LLRW generated or stored	Single letter G (generated) or S (stored) indicating type of waste streamed described.
LGENPRAC	LLRW generating practice	Practices at the facility generating the listed LLRW.
LSTORINF	LLRW storage information	Reason for storage of the listed LLRW.
HAZWASTE	Hazardous waste	Indicates if any of the facility's LLRW waste is considered hazardous. (Y or N)
YEAR	Year of questionnaire	The year (2 digits) for which data were reported.
COMMENT	Comment	Field for information found in the LLRW generating or storage sections of the questionnaire not fitting one of the above fields.

FILE ID: MIX_WAST.DBF

FILE NAME: Mixed Waste file (Section D-1 of the questionnaire)

DESCRIPTION: This file contains information on each LLRW stream which is considered hazardous. Information is given on the waste stream number, physical form, basis for documenting the information, hazardous component, source, and total volume of the LLRW stream generated.

FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	Original assigned identifier.
FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government entered as a code. (See Attachment 2)
COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the waste stream line number for a common ID number questionnaire. (Each waste stream will be numbered. 101, 102, etc.)

Data Field Descriptions

LLRWCODE	LLRW waste stream code	A number from Attachment 1 of the questionnaire identifying the LLRW waste stream containing hazardous materials.
PHYSFORM	Physical form	The physical form of the waste (aqueous, bulk liquid, compacted solid, etc.).
BASIS	Basis	Basis for judgement of constituents and characteristics of waste. Choices are tested (T) or process knowledge (PK).
HAZNAME name	Name of hazardous component	Names as they appear in the hazardous component section of the questionnaire without the EPA HAZ NO
SOURCE	Source of hazardous component	
TOTVOLGN	Total volume generated	Total volume of waste stream generated during the year reported in cubic feet/year. This value includes only the reported firm values.
ESUPVLGN	Estimated upper volume generated	The upper estimate of the total volume of waste stream generated during the year reported in cubic feet/year. This value includes either the firm value, the upper values for less than estimates or the upper values for range estimates.
ESLOVLGN	Estimated lower volume generated	The lower estimate of the total volume of waste stream generated during the year reported in cubic feet/year. This value includes either the firm value or the lower values for range estimates.
MIXTPURE	Mixture or Pure	Indicates whether the hazardous component is pure (P) or part of a mixture (M).
YEAR	Year of questionnaire	The year (2 digits) for which data were reported.
GROUPID	Group identification	An identification assigned by the ORNL committee.
COMMENT	Comment	Field for information found in the Mixed Waste section of the questionnaire not fitting one of the above fields.

Three fields that would normally be found in the above file along with an internal and external counting number assigned in sequence and the identification number are in a subfile to the above file. This subfile will have a record for each chemical that is listed in the Hazardous name field.

SUB FILE ID: MIX_SUB.DBF

IDNUMBER	Identification number	Original assigned identifier.
COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the waste stream line number for a common ID number questionnaire. (Each waste stream line is numbered 101, 102, etc.)
HAZCHEM	Name of hazardous chemical	Chemical name of one of the components of the hazardous component name (if only one is found in the above field it will repeated here)
CASRN	CAS Registry number of chemical	Chemical Abstract Service Registry number for the preceding chemical.
EPAHAZNO	EPA Hazardous Waste No.	Number from Attachment 2 of the questionnaire, selected by using the chemical name.
COUNTER	Repeat for COUNTNO	A sequential number assigned to identify each individual chemical in the hazardous mixture.(1, 2, 3, etc.)

FILE ID: TREATMEN.DBF

FILE NAME: Mixed Waste treatment file (Section D-2 of the questionnaire)

DESCRIPTION:		This file contains information on each LLRW stream listed in the mixed waste file. It includes the major radionuclides, the RAD waste classification, the cumulative activity, treatment site, type of treatment, and the volume treated during the year.
FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	Original assigned identifier.
FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government, entered as a code. (See Attachment 2)

Data Field Descriptions

COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the record number for a common ID number questionnaire. (Lines of information are numbered 101, 102, etc.)
LLRWCODE	LLRW waste stream code	A number found in Attachment 1 of the questionnaire identifying the LLRW waste stream containing hazardous materials.
MAJNUCLI	Major radionuclides	Major radionuclides found in the LLRW waste stream.
3H	Hydrogen-3	True or false: the hydrogen-3 isotope is found in the waste stream.
14C	Carbon-14	True or false: the carbon-14 isotope is found in the waste stream.
32P	Phosphorus-32	True or false: the phosphorus-32 isotope is found in the waste stream.
59NI	Nickel-59	True or false: the nickel-59 isotope is found in the waste stream.
63NI	Nickel-63	True or false: the nickel-63 isotope is found in the waste stream.
90SR	Strontium-90	True or false: the strontium-90 isotope is found in the waste stream.
137CS	Cesium-137	True or false: the cesium-137 isotope is found in the waste stream.
134CS	Cesium-134	True or false: the cesium-134 isotope is found in the waste stream.
60CO	Cobalt-60	True or false: the cobalt-60 isotope is found in the waste stream.
35S	Sulfur-35	True or false: the sulfur-35 isotope is found in the waste stream.
125I	Iodine-125	True or false: the iodine-125 isotope is found in the waste stream.
51CR	Chromium-51	True or false: the chromium-51 isotope is found in the waste stream.

22NA	Sodium-22	True or false: the sodium-22 isotope is found in the waste stream.
36CL	Chlorine-36	True or false: the chlorine-36 isotope is found in the waste stream.
235U	Uranium-235	True or false: the uranium-235 isotope is found in the waste stream.
239U	Uranium-239	True or false: the uranium-239 isotope is found in the waste stream.
65ZN	Zinc-65	True or false: the zinc-65 isotope is found in the waste stream.
207BI	Bismuth-207	True or false: the bismuth-207 isotope is found in the waste stream.
54MN	Manganese-54	True or false: the manganese-54 isotope is found in the waste stream.
59FE	Iron-59	True or false: the iron-59 isotope is found in the waste stream.
133BA	Barium-133	True or false: the barium-133 isotope is found in the waste stream.
CLASS	Classification	The radioactive waste classification (A, B, C).
MIXTPURE	Mixture or Pure	Indicates whether the radioactive component is pure (P) or part of a mixture (M).
CUMACTIV	Cumulative Activity	Cumulative activity in millicuries for each waste during year reported. This value includes firm values, the upper values for less than estimates, and the upper values for range estimates.
ESUPCUAC	Estimated upper cumulative activity	Upper estimate of the cumulative activity in millicuries for each waste during year reported. This value includes the upper values for less than estimates and the upper values for range estimates.
ESLOCUAC	Estimated lower cumulative activity	Lower estimate of the cumulative activity in millicuries for each waste during year reported. This value includes only the lower value for range estimates.

TREATSIT	Treatment On-Site	True or false: the waste was treated onsite.
TREATTYP	Treatment type	Waste treatment, burned for energy, storage for decay, etc., entered as a code. (See Attachment 4)
VOLTREAT	Volume treated	Volume of mixed waste treated during the year reported in cubic feet. This value includes only the reported firm values.
ESUPVLTR	Estimated upper volume treated	Upper estimate for the volume of mixed waste treated during the year reported in cubic feet. This value includes the reported firm values, the upper values for less than estimates or the upper values for range estimates.
ESLOVLTR	Estimated lower volume treated	Lower estimate for the volume of mixed waste treated during the year reported in cubic feet. This value includes either the firm values or the lower values for range estimates.
YEAR	Year of questionnaire	Year (2 digits) for which data were reported.
GROUPID	Group identification	An identification assigned by the ORNL committee.
COMMENT	Comment	Field for information found in the Mixed Waste radioactivity section of the questionnaire not fitting one of the above fields.

FILE ID: TREA_WAS.DBF

FILE NAME: Treated Mixed Waste file (Section D-3 of the questionnaire)

DESCRIPTION: This file contains information on the results of the treatment of each LLRW stream listed in the mixed waste file. It includes the after treatment volume, activity, and effect on the hazardous component, and the volume of the LLRW stream requiring ultimate disposal.

FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	Original assigned identifier.

Data Field Descriptions

FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government, entered as a code. (See Attachment 2)
COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the record number for a common ID number questionnaire. (Lines of information will be 101, 102, etc.)
LLRWCODE	LLRW waste stream code	A number from Attachment 1 of the questionnaire identifying the LLRW waste stream containing hazardous materials.
TREATVOL	After treatment volume	The volume (cubic feet) of the mixed waste after treatment. This value includes only the reported firm values.
MIXTPURE	Mixture or Pure	Indicates whether the hazardous component is pure (P) or part of a mixture (M).
ESUPTRVL	Estimated upper after treat volume	Upper estimate of the volume (cubic feet) of the mixed waste after treatment. This value includes the reported firm value, the upper values for less than estimates or the upper values for range estimates.
ESLOTRVL	Estimated lower after treat volume	Lower estimate of the volume (cubic feet) of the mixed waste after treatment. This value includes the firm values or the lower values for range estimates.
TREATACT	After treatment activity	Radioactivity of the mixed waste after treatment. This value includes firm values, the upper values for less than estimates, and the upper values for range estimates.
ESUPTRAC	Estimated upper after treat activity	Upper estimate of the radioactivity of the mixed waste after treatment. This value includes the upper values for greater than estimates and the upper values for range estimates.
ESLOTRAC	Estimated lower after treat activity	Lower estimate of the radioactivity of the mixed waste after treatment. This value includes only the lower value for range estimates.
TRTHAZCO	Hazardous component	Effect of the treatment on the hazardous component in the mixed waste.

VOLDISPO	Volume for disposal	Volume (cubic feet) of the mixed waste remaining after treatment requiring ultimate disposal. This value includes only the firm values.
ESUPVLDS	Estimated upper volume for disposal	Upper estimate of the volume (cubic feet) of the mixed waste remaining after treatment requiring ultimate disposal. This value includes the firm values, the upper values for greater than estimates or the upper values for range estimates.
ESLOVLDS	Estimated lower volume for disposal	Lower estimate of the volume (cubic feet) of the mixed waste remaining after treatment requiring ultimate disposal. This value includes either the firm values or the lower values for range estimates.
YEAR	Year of questionnaire	Year (2 digits) for which data were reported.
GROUPID	Group identification	An identification assigned by the ORNL committee.
COMMENT	Comment	Field for information found in the treated Mixed Waste section of the questionnaire not fitting one of the above fields.

FILE ID: STOR_WAS.DBF

FILE NAME: Stored Mixed Waste file (Section E-1 of the questionnaire)

DESCRIPTION: This file contains information on stored mixed waste streams. Information includes the physical form and the basis for that judgement, the hazardous component and its source, and the cumulative amount in storage at the end of the reporting year.

FIELD ID	FIELD NAME	FIELD DESCRIPTION
IDNUMBER	Identification number	Original assigned identifier.
FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government, entered as a code. (See Attachment 2)

COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the waste stream line number for a common ID number questionnaire. (Each waste stream line will be numbered 501, 502, etc.))
LLRWCODE	LLRW waste stream code	Number from Attachment 1 of the questionnaire identifying the LLRW waste stream containing hazardous materials.
PHYSFORM	Physical form	Physical form of the waste (aqueous, bulk liquid, compacted solid, etc.).
BASIS	Basis	Basis for judgement of constituents and characteristics of waste. Choices are tested (T) or process knowledge (PK).
HAZNAME	Name of hazardous component	Names as they appear in the hazardous component name section of the questionnaire without the EPA HAZ NO
SOURCE	Source of hazardous component	
AMTSTORD	Amount stored	Cumulative amount (cubic feet/year) of mixed waste in storage as of December 31 of reporting year. This value includes firm values only.
MIXTPURE	Mixture or Pure	Indicates whether the hazardous component is pure (P) or part of a mixture (M).
ESUPAMST	Upper estimate of amount stored	Upper estimate of the cumulative amount (cubic feet/year) of mixed waste in storage as of December 31 of the reporting year. This value includes the firm values, the upper values for less than estimates or the upper values for range estimates.
ESLOAMST	Lower estimate of amount stored	Lower estimate of the cumulative amount (cubic feet/year) of mixed waste in storage as of December 31 of the reporting year. This value includes either the firm value or the lower values for range estimates.
YEAR	Year of questionnaire	Year (2 digits) for which data were reported.
GROUPID	Group identification	An identification assigned by the ORNL committee.
COMMENT	Comment	Field for information found in the stored Mixed Waste

		section of the questionnaire not fitting one of the above fields.

Three fields that would normally be found in the above file along with an internal and external counting number assigned in sequence and the identification number are in a subfile to the above file. This subfile will have a record for each chemical that is listed in the Hazardous name field.

SUB FILE ID: STOR_SUB.DBF

IDNUMBER	Identification number	Original assigned identifier.
COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the waste stream line number for a common ID number questionnaire. (Each waste stream line will be numbered 501, 502, etc.))
HAZCHEM	Name of hazardous chemical	Chemical name of one of the components of the hazardous component name (if only one component is found in the above field it will repeated here)
CASRN	CAS Registry number of chemical	Chemical Abstract Service Registry number for the preceding chemical.
EPAHAZNO	EPA Hazardous Waste No.	This number from Attachment 2 of the questionnaire. It should be selected by using the chemical name listed above.
COUNTER	Repeat for COUNTNO	A sequential number assigned to identify each individual chemical contained in the hazardous mixture. (Numbers will be 1, 2, 3, etc.)

FILE ID: RADIOACT.DBF

FILE NAME: Radioactivity of stored Mixed Waste file (Section E-2 of the questionnaire)

DESCRIPTION:		This file contains information on the major radionuclides in the stored mixed waste. It includes the major radionuclides, RAD waste classification, cumulative activity, and reason for storage.
FIELD ID	**FIELD NAME**	**FIELD DESCRIPTION**
IDNUMBER	Identification number	Original assigned identifier.

Data Field Descriptions

FACCATEG	Facility Category	Categories are nuclear reactor, medical, academic, industrial or government, entered as a code. (See Attachment 2)
COUNTNO	Repeat for IDNUMBER	A sequential number assigned to indicate the record number for a common ID number questionnaire. (Lines of information will be numbered 101, 102, etc.)
LLRWCODE	LLRW waste stream code	A number from Attachment 1 of the questionnaire which identifies the LLRW waste stream containing hazardous materials.
MAJNUCLI	Major radionuclides	List of the major radionuclides found in the LLRW waste stream.
3H	Hydrogen-3	True or false: the hydrogen-3 isotope is found in the waste stream.
14C	Carbon-14	True or false: the carbon-14 isotope is found in the waste stream.
32P	Phosphorus-32	True or false: the phosphorus-32 isotope is found in the waste stream.
59N	Nickel-59	True or false: the nickel-59 isotope is found in the waste stream.
63NI	Nickel-63	True or false: the nickel-63 isotope is found in the waste stream.
90SR	Strontium-90	True or false: the strontium-90 isotope is found in the waste stream.
137CS	Cesium-137	True or false: the cesium-137 isotope is found in the waste stream.
134CS	Cesium-134	True or false: the cesium-134 isotope is found in the waste stream.
60CO	Cobalt-60	True or false: the cobalt-60 isotope is found in the waste stream.
35S	Sulfur-35	True or false: the sulfur-35 isotope is found in the waste stream.

125I	Iodine-125	True or false: the iodine-125 isotope is found in the waste stream.
51CR	Chromium-51	True or false: the chromium-51 isotope is found in the waste stream.
22NA	Sodium-22	True or false: the sodium-22 isotope is found in the waste stream.
36CL	Chlorine-36	True or false: the chlorine-36 isotope is found in the waste stream.
235U	Uranium-235	True or false: the uranium-235 isotope is found in the waste stream.
239U	Uranium-239	True or false: the uranium-239 isotope is found in the waste stream.
65ZN	Zinc-65	True or false: the zinc-65 isotope is found in the waste stream.
207BI	Bismuth-207	True or false: the bismuth-207 isotope is found in the waste stream.
54MN	Manganese-54	True or false: the manganese-54 isotope is found in the waste stream.
59FE	Iron-59	True or false: the iron-59 isotope is found in the waste stream.
133BA	Barium-133	True or false: the barium-133 isotope is found in the waste stream.
CLASS	Classification	Radioactive waste classification (A, B, C).
CUMACTIV	Cumulative Activity	Cumulative activity in millicuries for each mixed waste as of December 31 of the reporting year. This value includes firm values, the upper values for less than estimates, and the upper values for range estimates.
MIXTPURE	Mixture or Pure	Indicates whether the radioactive component is pure (P) or part of a mixture (M).
ESUPCUAC	Upper estimate of cumulative activity	Upper estimate of the cumulative activity in millicuries for each mixed waste as of December 31 of the reporting year. This value includes the upper values

		for less than estimates and for range estimates.
ESLOCUAC	Lower estimate of cumulative activity	Lower estimate of the cumulative activity in millicuries for each mixed waste as of December 31 of the reporting year. This value includes only the lower values for range estimates.
REASSTOR	Reason stored	Reason for the mixed waste storage (storage for decay, unable to treat, unable to ship, etc.). (See Attachment 5)
YEAR	Year of questionnaire	Year (2 digits) for which data were reported.
GROUPID	Group identification	An identification assigned by the ORNL committee.
COMMENT	Comment	Field for information found in the radioactivity of stored Mixed Waste section of the questionnaire not fitting one of the above fields.

ATTACHMENT 1

Decode for IDNUMBER

This field will be a 6 character alphanumeric field as follows:

1st position:
- U - Utilities
- M - Medical
- A - Academic
- I - Industrial
- G - Government

2nd position:
- 1 - ORNL list
- 2 - Shippers List Excluding ORNL list
- 3 - NRC with EPA permit
- 4 - NRC without EPA Permit

3rd, 4th, 5th, 6th position: 1 to 9999, assigned by ORNL committee and is the sample number.

ATTACHMENT 2

FACILITY CATEGORY DECODE FILE (FACCATEG)

Nuclear Reactor Facility	100
Boiling Water Reactor	110
Pressurized Water Reactor	120
Research & Test Reactors	130
Medical (non-Federal)	200
Hospital	210
<250 beds	211
250-750 beds	212
>750 beds	213
Medical college/hospital	220
Laboratory	230
Research	240
Academic	300
<10,000 students	310
10,000-20,000 students	320
>20,000 students	330
Industrial	400
Manufacturing	410
<50 employees on site	411
50-200 employees on site	412
>200 employees on site	413
Research and Development	420
Decontamination facility & waste reduction	430
Sealed source/gauge/instrument user	440
Waste broker/processor	450
Nuclear fuel cycle other than power reactors	460
Commercial radiopharmacy	470
Government	500
Federal	510
Hospital	511
Research & Development	512
Military	513
State	520
Other	530*

*530 is for any type of facility which appears frequently in the questionnaires and does not have a category listed.

ATTACHMENT 3

DECODE FOR EPA FACILITY CLASSIFICATION(EPACLASS)

Large quantity generator (>1000 Kg/month)	LQ
Small quantity generator (100-1000 Kg/month)	SQ
Conditionally exempt small quantity generator (<100 Kg/month)	CON
No EPA Calssification	NO

ATTACHMENT 4

TREATMENT TYPE DECODE FILE

Burned for energy	1
Evaporation	2
Incineration	3
Not treated	4
Radioactive contaminant removal	5
Solidification	6
Storage for decay	7
Compaction	8
Neutralization	9
Filtration	10

ATTACHMENT 5

REASON STORED DECODE FILE

Accumulation	10
Evaluating options	20
Holding for deregulation	30
Storage for decay	40
Unable to treat	50
Unable to ship	60
Using as a shield	70

APPENDIX D

DETAILED "AS REPORTED" DATA TABLES

Table D.1 Mixed waste generated in 1990
[As reported (ft^3)]

	Facility category					
	Academic	Government	Industrial	Medical	Nuclear utilities	Total
Northeast Compact (79)[1]	283	4	1,216	217	62	1,782
Appalachian Compact (136)[1]	1,882	11,989	3,148	474	1,388	18,881
Southeast Compact (131)[1]	3,284	3,566	5,896	2,923	2,687	18,356
Central States Compact (30)[1]	352	42	8	54	232	688
Midwest Compact (166)[1]	6,359	448	4,614	201	860	12,482
Central Midwest Compact (47)[1]	1,531	787	640	770	2,610	6,338
Rocky Mountain Compact (11)[1]	135	9	120	0[2]	0[3]	264
Northwest Compact (48)[1]	781	469	42	384	30	1,706
Southwestern Compact (125)[1]	2,547	160	2,143	2,401	5,010	12,261
Unaligned						
DC (11)[1]	140	533	0[2]	4	0[4]	677
ME (7)[1]	10	0[2]	0[3]	0[3]	112	122
MA (77)[1]	1,666	23	637	599	70	2,995
NH (3)[1]	0[2]	0[3]	0[2]	0[2]	0[3]	0[3]
NY (110)[1]	982	249	575	1,109	160	3,075
PR (0)[1]	0[5]	0[5]	0[5]	0[2]	0[4]	0[3]
RI (1)[1]	0[2]	0[2]	0[2]	0[3]	0[4]	0[3]
TX (27)[1]	269	45	17	1,015	27	1,373
VT (5)[1]	200	0[2]	0[3]	0[2]	27	227
TOTAL (1,014)[1]	20,421	18,324	19,056	10,151	13,275	81,227

[1]Numbers in ( ) represent the number of facilites returning questionnaires within this compact/state.
[2]No facilities were surveyed in this particular category (e.g., no industrial facilities were surveyed in New Hampshire).
[3]At least one facility in this category within the compact/state returned a MW survey and all facilities returning surveys in this category and within the compact/state reported generating no mixed waste.
[4]No facilities are present in this category within the compact/state (i.e., nuclear reactors in DC, PR, & RI).
[5]Facilities were surveyed in this category, but none of these facilities returned their surveys.

Table D.2 National Mixed Waste Profile
[Generation rate in 1990 (ft^3/year)]

As Reported

	Hazardous waste stream												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other[1]	Total
Academic	18,996	10	351	0	0	181	32	0	4	0	49	797	20,420
Government	13,599	4	999	0	0	2,475	165	0	83	1	990	8	18,324
Industry	9,600	381	298	0	70	1,918	975	331	518	0	1,139	3,825	19,055
Medical	9,621	0	217	0	0	268	17	7	0	0	2	20	10,151
Nuclear utilities	10	4,588	49	0	3,585	1,124	1,200	4	247	8	152	2,308	13,276
TOTAL	51,826	4,983	1,914	0	3,655	5,966	2,389	342	852	9	2,332	6,958	81,226

Weighted

	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other[1]	Total
Academic	26,918	15	512	0	0	251	44	0	5	0	71	1,165	28,982
Government	20,315	4	1,179	0	0	3,525	200	0	100	1	1,167	9	26,500
Industry	34,088	531	494	0	319	4,091	1,365	413	643	0	1,442	7,043	50,430
Medical	18,862	0	269	0	0	676	43	25	0	0	2	27	19,904
Nuclear utilities	11	4,709	50	0	3,679	1,154	1,231	4	254	8	156	2,369	13,625
TOTAL	100,194	5,259	2,504	0	3,998	9,697	2,883	442	1,002	9	2,838	10,613	139,441

Table D.3 National Mixed Waste Profile
[Amount in storage as of 12/31/90 (ft^3)]

As reported

	Hazardous waste stream												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other	Total
Academic	3,068	4	144	0	0	366	22	1	1	0	49	220	3,874
Government	713	5	12	0	0	617	204	0	82	1	0	58	1,692
Industry	1,304	937	110	99	130	557	52	1,967	825	8,000	1	2,096	16,078
Medical	947	0	3	0	0	91	0	0	0	0	1	117	1,158
Nuclear utilities	146	4,931	499	0	8,380	1,250	4,336	406	738	10	352	354	21,403
TOTAL	6,178	5,877	768	99	8,510	2,881	4,614	2,374	1,646	8,011	403	2,845	44,205

Weighted

	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other	Total
Academic	4,289	6	201	0	0	526	30	1	1	0	68	325	5,448
Government	1,598	6	21	0	0	746	247	0	100	1	0	69	2,789
Industry	5,157	1,217	215	122	393	1,163	171	2,448	1,025	26,304	1	4,065	42,280
Medical	1,622	0	4	0	0	443	0	0	0	0	1	157	2,227
Nuclear utilities	168	5,061	512	0	8,600	1,284	4,451	416	757	11	361	363	21,985
TOTAL	12,834	6,290	953	122	8,993	4,162	4,899	2,865	1,883	26,316	431	4,979	74,729

Table D.4 National Mixed Waste Profile
[Waste generated in 1990 that currently cannot be treated(ft^3)]

	Hazardous waste stream												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other	Total
Academic	72	2	23	0	0	128	1	0	0	0	15	12	253
Government	639	0	9	0	0	311	143	0	83	0	0	0	1,183
Industry	1	6	34	0	1	24	45	32	0	0	0	227	370
Medical	175	0	0	0	0	2	6	0	0	0	0	309	493
Nuclear utilities	0	295	5	0	866	76	119	2	37	0	23	7	1,432
TOTAL	887	303	71	0	867	525	314	34	120	0	38	571	3,731

	Weighted												
	LSF	Oil	Org-Cl	Org-Fl	CFC	Org-Other	Pb	Hg	Cr	Cd	Corr	Other	Total
Academic	105	3	31	0	0	175	2	0	0	0	22	16	353
Government	794	0	13	0	0	375	173	0	100	0	0	0	1,455
Industry	2	21	90	0	1	63	148	40	0	0	0	469	834
Medical	330	0	0	0	0	3	8	0	0	0	0	384	726
Nuclear utilities	0	303	5	0	889	79	123	2	38	0	23	8	1,470
TOTAL	1,231	327	139	0	890	695	454	42	138	0	45	877	4,838

Table D.5 Facility mixed waste profile – Academic
As reported (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics	18,996	133	39,878	165	3,068
Liquid Scintillation Fluids	10	10	1	2	4
Waste Oil	351	40	277	23	144
Chlorinated Organics	0	0	0	0	0
Fluorinated Organics	0	0	0	0	0
Chlorinated Fluorocarbons (CFCs)	181	117	305	34	366
Other Organics					
Metals	32	14	1	1	22
Lead	0	0	0	0	1
Mercury	4	0	2	0	1
Chromium	0	0	0	0	0
Cadmium					
Aqueous Corrosives	49	43	0	15	49
Other Hazardous Materials	797	30	125	12	220
TOTAL	20,420	387	40,589	252	3,875

Table D.6 Facility mixed waste profile – Government
As reported (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid Scintillation Fluids	13,599	2,313	8,890	644	713
Waste Oil	4	0	0	0	5
Chlorinated Organics	999	0	0	9	12
Fluorinated Organics	0	0	0	0	0
Chlorinated Fluorocarbons (CFCs)	0	0	0	0	0
Other Organics	2,475	4,790	90	306	617
Metals					
Lead	165	0	0	143	204
Mercury	0	0	0	0	0
Chromium	83	0	0	83	82
Cadmium	1	0	0	0	1
Aqueous Corrosives	990	1	0	0	0
Other Hazardous Materials	8	0	0	0	58
TOTAL	18,324	7,104	8,980	1,185	1,692

Table D.7 Facility mixed waste profile – Industrial
As reported (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid Scintillation Fluids	9,600	787	8,202	1	1,304
Waste Oil	381	5	1	6	937
Chlorinated Organics	298	8	72	34	110
Fluorinated Organics	0	0	0	0	99
Chlorinated Fluorocarbons (CFCs)	70	0	0	1	130
Other Organics	1,918	1,148	267	24	557
Metals					
Lead	975	0	45	45	52
Mercury	331	22	0	32	1,967
Chromium	518	0	0	0	825
Cadmium	0	0	0	0	8,000
Aqueous Corrosives	1,139	0	0	0	1
Other Hazardous Materials	3,825	2,292	105	227	2,096
TOTAL	19,055	4,262	8,692	370	16,078

Table D.8 Facility mixed waste profile – Medical
As reported (ft^3)

Hazardous Stream	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Organics					
Liquid Scintillation Fluids	9,621	353	8,434	175	947
Waste Oil	0	0	0	0	0
Chlorinated Organics	217	0	136	0	3
Fluorinated Organics	0	0	0	0	0
Chlorinated Fluorocarbons (CFCs)	0	0	0	0	0
Other Organics	268	2	235	2	91
Metals					
Lead	17	10	7	6	0
Mercury	7	0	8	0	0
Chromium	0	0	0	0	0
Cadmium	0	0	0	0	0
Aqueous Corrosives	2	0	1	0	1
Other Hazardous Materials	20	0	0	309	117
TOTAL	10,152	365	8,821	492	1,159

Table D.9 Facility mixed waste profile – Nuclear utilities
As reported (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid Scintillation Fluids	10	0	4	0	146
Waste Oil	4,588	4,216	548	295	4,931
Chlorinated Organics	49	0	0	5	499
Fluorinated Organics	0	0	0	0	0
Chlorinated Fluorocarbons (CFCs)	3,585	115	11	866	8,380
Other Organics	1,124	15	7	76	1,250
Metals					
Lead	1,200	0	8	119	4,336
Mercury	4	0	0	2	406
Chromium	247	134	0	37	738
Cadmium	8	3	0	0	10
Aqueous Corrosives	152	23	0	23	352
Other Hazardous Materials	2,308	163	2,215	7	354
TOTAL	13,275	4,669	2,793	1,430	21,402

Table D.10 Facility mixed waste profile – All facilities
As reported (ft^3)

	Amount generated in 1990	Amount treated on-site in 1990	Amount treated off-site in 1990	Amount generated in 1990 that cannot be currently treated	Amount in storage as of 12/31/90
Hazardous Stream					
Organics					
Liquid Scintillation Fluids	51,826	3,585	65,408	887	6,178
Waste Oil	4,983	4,231	550	303	5,877
Chlorinated Organics	1,914	48	485	71	768
Fluorinated Organics	0	0	0	0	99
Chlorinated Fluorocarbons (CFCs)	3,655	115	12	867	8,510
Other Organics	5,966	6,073	904	525	2,881
Metals					
Lead	2,389	24	61	314	4,614
Mercury	342	22	8	34	2,374
Chromium	852	134	2	120	1,646
Cadmium	9	2	0	0	8,011
Aqueous Corrosives	2,332	67	1	38	403
Other Hazardous Materials	6,958	2,486	2,445	571	2,845
TOTAL	81,226	16,787	69,876	3,730	44,206

Table D.11 National Mixed Waste Profile
[Amount generated in 1990 (ft^3)]

Hazardous stream = other

FAC ID	Vol	Name	Source
A10032	1.9	TRASH	CLEANUP
A10056	0.1	URANYL NITRATE	ELECTION MICROSCOPY
A10066	4.0	Uranyl Acetate, Nitrate	Electron Mic. stains &
A10077	0.1	SODIUM CYANIDE	RESEARCH
A10077	0.1	POTASSIUM CYANIDE	RESEARCH
A10089	20.0	BIOLOGICAL WASTE	
A10089	40.0	TRASH	
A10089	10.0	METALS	LAB EXPERIMENTS
A10090	10.0	TRASH	
A10096	0.5	OSMIUM TETROXIDE	STAINING PROCEDURES
A10097	1.3	ARSENIC AND 32P	
A10101	0.9	BIOLOGICAL WASTE	
A10101	63.0	TRASH	
A10101	0.9	SEALED SOURCES	SEALED SOURCES
A10101	0.6	PAINT WASTE	
A20009	7.5	TRASH	
A20011	10.0	TNT	USED FOR RESARCH CLEANI
A20026	22.5	RADIONUCLIDES	RESEARCH
A20026	4.0	RADIONUCLIDES	RESEARCH
A20044	0.1	URANYL ACETATE	
A20061	7.5	PAPER, PLASTIC GLASS	LAB EXPERIMENTS IN BIOL
A20071	7.5	TRASH	TRASH
A20101	562.5	COMPACTED SOLID TRASH	RESEARCH
A20101	15.0	SOIL	RESEARCH
A20190	11.5	BERYLLIUM	SEALED SOURCES
G10004	7.5	MISCELLANEOUS	
I10048	7.4	MISCELLANEOUS	
I10079	22.5	CORROSIVITY, REACTIVITY	EXPIRED PRODUCTS
I10113	7.5	MISCELLANEOUS	
I10128	2180.0	CADMIUM, CHROMIUM, LEAD	INCINERATOR ASH
I10155	272.0	METAL MIXTURE	ANALYTICAL PROCESS
I10155	227.6	METAL MIXTURE	ANALYTICAL PROCESS
I10165	30.0	BIOLOGICAL WASTE	RESEARCH
I10168	4.0	RESIDUAL SOILS	COMBUSTION OF 14C RESID
I20056	22.5	TOLUENE, GRANITE SALTS	BIOCHEMISTRY PROTEIN AS
I20059	15.0	SEALED SOURCES - NICKEL	PRODUCTION SOURCES WAST
I20111	82.5	SODIUM AZIDE	MANUFACTURE PROCESS
I20122	4.0	THORIUM NITRATE	
I20129	37.0	MG-TH ALLOY	
I20196	15.0	CARCASSESS	RESEARCH ANIMALS
I20196	15.0	URINE AND FECES	RESEARCH ANIMALS
I20196	15.0	TRASH	SAMPLE PREP, LAB BENCH
I20234	750.0	BARIUM	MELTING OF MAG/2% TH ME
I20234	100.0	METAL CLEANING SOLUTION	CASTING CLEANING
I20288	1.0	MISCELLANEOUS	
I20340	10.0	SODIUM AZIDE	BUFFER COMPONENT
I40013	7.0	HAZARDOUS WASTE LIQUID	MANUFACTURE OF RADIOLAB
M10049	6.0	ANIMAL CARCASSES	TRITIUM AND C-14
M10049	2.0	ANIMAL CARCASSES	Ca-45
M10053	7.5	LAB CLEANUP	LAB CLEANING
M10069	0.2	URANYL NITRATE/ACETATE	
P10006	27.3	LEAD, MERCURY, CADMIUM	PAINT/SOLVENTS, PAINT/T
P10017	7.5	DRIED PAINT	MAINTENANCE ACTIVITIES
P10026	0.1	EPOXY PAINT	MAINTENANCE
P10030	23.0	LEAD, CHROMIUM, SELENIU	PUMPS

Table D.11 (continued)

FAC ID	Vol	Name	Source
P10040	15.0	LEAD, CADMIUM, CARBON T	SPENT SOLVENTS - DEGREA
P10042	2188.0	LEAD, OIL, SOLVENTS AND	EQUIPMENT MAINTENANCE
P10042	7.5	PROCESSING USED OIL/LEA	FILTER BAGS
P10045	5.0	CORROSIVE LIQUID, CADMI	EQUIPMENT REPAIR/REPLAC
P10048	10.0	LEAD, MERCURY, BARIUM,	DECONTAMINATION
P10048	25.0	IGNITABLE, MERCURY, BAR	MAINTENANCE ACTIVITIES
	Total 6,958		

Notes:

The first column is the facility ID Number: A = Academic, G = Government, I = Industrial, M = Medical, P = Nuclear Power Facilities.

The second column is the amount of this type waste generated in 1990. The decision to place a particular waste stream in the "Other " category was made by ORNL, based on information provided in the next two columns and on other information contained in the completed questionnaire.

The third and fourth column contain abbreviated comments on the hazardous name and source that give some indication of the type of material present in this stream.

APPENDIX E

ESTIMATION PROCEDURES

ESTIMATION PROCEDURES

National Profile on Commercially Generated Low-Level Radioactive Mixed Waste

The steps for estimation of volumes related to the National Profile on Commercially Generated Low-Level Radioactive Mixed Wastes and consistent with stratified random sampling as presented in Appendix A of "Technical Letter Report for Task Three FIN L-1647-0," September 30, 1991, and in Appendix A of this report, are as follows.

Step 1. Assume that the original frame construction placed each facility in its correct stratum ij as indicated in Table 1. At this point, the extent to which this assumption is false is believed to be negligible.

			j				
			1	2	3	4	
			ORNL List	Shipper's List Exclusive ORNL List	NRC List With EPA Permit	NRC List Without EPA Permit	TOTALS
	P	Power Plant	78	0	0	0	78
	M	Medical	66	360	19	83	528
i	A	Academic	85	192	77	134	488
	I	Industrial	116	900	166	546	1728
	G	Government	18	80	5	155	258
		TOTALS	363	1532	267	918	3080

TABLE 1. Original (Sampled) Universe Sizes

Step 2. A stratified random sample of size 1334 was selected (i.e., a simple random sample was selected within each stratum and independently of the other strata) as shown in Table 2.

			j				
			1	2	3	4	
			ORNL List	Shipper's List Exclusive ORNL List	NRC List With EPA Permit	NRC List Without EPA Permit	TOTALS
	P	Power Plant	78	0	0	0	78
	M	Medical	66	95	1	4	166
i	A	Academic	85	192	77	44	398
	I	Industrial	116	355	24	39	534
	G	Government	18	80	5	55	158
		TOTALS	363	722	107	142	1334

TABLE 2. Original Stratified Random Sample Size Distribution

Step 3. Following Step 2, 95 *additional* facilities were identified from late submittals from various states and included in the sample with certainty with the following distribution assignments. Note that no attempt was made to identify and eliminate possible duplicates among the 95 that might have already been in the universe or sample.

		j 1	2	3	4	TOTALS
	P	0	0	0	0	0
	M	13	0	0	0	13
i	A	26	0	0	0	26
	I	53	0	0	0	53
	G	3	0	0	0	3
	TOTALS	95	0	0	0	95

TABLE 3. Additional Sample Sizes

Step 4. Combining the results of Tables 1, 2, and 3 yields,

		j 1	2	3	4	TOTALS
i	P	78 + 0 = 78 78 + 0 = 78	0 + 0 = 0 0 + 0 = 0	0 + 0 = 0 0 + 0 = 0	0 + 0 = 0 0 + 0 = 0	78 78
	M	66 + 13 = 79 66 + 13 = 79	360 + 0 = 360 95 + 0 = 95	19 + 0 = 19 1 + 0 = 1	83 + 0 = 83 4 + 0 = 4	541 179
	A	85 + 26 = 111 85 + 26 = 111	192 + 0 = 192 192 + 0 = 192	77 + 0 = 77 77 + 0 = 77	134 + 0 = 134 44 + 0 = 44	514 424
	I	116 + 53 = 169 116 + 53 = 169	900 + 0 = 900 355 + 0 = 355	166 + 0 = 166 24 + 0 = 24	546 + 0 = 546 39 + 0 = 39	1781 587
	G	18 + 3 = 21 18 + 3 = 21	80 + 0 = 80 80 + 0 = 80	5 + 0 = 5 5 + 0 = 5	155 + 0 = 155 55 + 0 = 55	261 161
	TOTALS	458 458	1532 722	267 107	918 142	3175 1429

TABLE 4. Preliminary Universe and Sample Sizes

where within stratum ij the top number is the preliminary number of facilities in the sampling frame and the bottom number is the preliminary number of facilities in the sample.

Step 5. Following a review (based on matching) of all sample facilities during data collection, duplicates were discovered as follows.

Case	First Stratum	Second Stratum	Number of Duplicates	Recommended Action for Identified Sample Duplicates
1	A1	A1	1	Delete 1 from A1 sample
2	A1	A2	22	Delete 22 from A2 sample
3	A1	A3	1	Delete 1 from A3 sample
4	A1	A4	3	Delete 3 from A4 sample
5	A1	M2	2	Delete 2 from A1 sample
6	A2	A2	3	Delete 3 from A2 sample
7	A2	A3	3	Delete 3 from A3 sample
8	A2	A4	11	Delete 11 from A4 sample
9	A2	I2	1	Delete 1 from A2 sample
10	A2	M1	1	Delete 1 from A2 sample
11	A2	M4	1	Delete 1 from M4 sample
12	A3	M1	1	Delete 1 from M1 sample
13	G1	G2	4	Delete 4 from G2 sample
14	G1	G4	1	Delete 1 from G4 sample
15	G1	M1	2	Delete 2 from M1 sample
16	G1	P1	1	Delete 1 from G1 sample
17	G2	G2	1	Delete 1 from G2 sample
18	G2	G3	1	Delete 1 from G3 sample
19	G2	G4	2	Delete 2 from G4 sample
20	G2	P1	1	Delete 1 from G2 sample
21	G3	I2	1	Delete 1 from I2 sample
22	G4	I2	1	Delete 1 from I2 sample
23	G4	M1	1	Delete 1 from M1 sample
24	I1	I1	2	Delete 2 from I1 sample
25	I1	I2	16	Delete 16 from I2 sample
26	I1	M1	1	Delete 1 from I1 sample
27	I1	P1	2	Delete 2 from I1 sample
28	I2	I2	9	Delete 9 from I2 sample
29	I2	I4	1	Delete 1 from I4 sample
30	I2	P1	4	Delete 4 from I2 sample
31	I4	P1	1	Delete 1 from I4 sample
32	M1	M1	1	Delete 1 from M1 sample
33	M1	M2	2	Delete 2 from M2 sample
34	M2	M2	1	Delete 1 from M2 sample
			106	106

TABLE 5. Identified Duplicates in the Sample

In the last column of Table 5, each duplicate was deleted from the stratum sample for which it was least appropriate. The total number in each stratum (frame) was reduced proportionally by the number of sample deletions from that stratum.

Step 6. Thus, using the results of Tables 4 and 5, the following table gives the **STATE OF THE DATA BASE** used in the estimation procedures.

i \ j	1	2	3	4	TOTALS
P	$N_{P1} = 78$ $n_{P1} = 78$ $r_{P1} = 76$ $o_{P1} = 0$	$N_{P2} = 0$ $n_{P2} = 0$ $r_{P2} = 0$ $o_{P2} = 0$	$N_{P3} = 0$ $n_{P3} = 0$ $r_{P3} = 0$ $o_{P3} = 0$	$N_{P4} = 0$ $n_{P4} = 0$ $r_{P4} = 0$ $o_{P4} = 0$	$N_{P\cdot} = 78$ $n_{P\cdot} = 78$ $r_{P\cdot} = 76$ $o_{P\cdot} = 0$
M	$N_{M1} = 79\ (74/79) = 74$ $n_{M1} = 79\text{-}5 = 74$ $r_{M1} = 53$ $o_{M1} = 1$	$N_{M2} = 360\ (92/95) = 349$ $n_{M2} = 95\text{-}3 = 92$ $r_{M2} = 64$ $o_{M2} = 1$	$N_{M3} = 19$ $n_{M3} = 1$ $r_{M3} = 1$ $o_{M3} = 0$	$N_{M4} = 83\ (3/4) = 63$ $n_{M4} = 4\text{-}1 = 3$ $r_{M4} = 2$ $o_{M4} = 0$	$N_{M\cdot} = 505$ $n_{M\cdot} = 170$ $r_{M\cdot} = 120$ $o_{M\cdot} = 2$
A	$N_{A1} = 111\ (108/111) = 108$ $n_{A1} = 111\text{-}3 = 108$ $r_{A1} = 80$ $o_{A1} = 0$	$N_{A2} = 192\ (165/192) = 165$ $n_{A2} = 192\text{-}27 = 165$ $r_{A2} = 111$ $o_{A2} = 0$	$N_{A3} = 77\ (73/77) = 73$ $n_{A3} = 77\text{-}4 = 73$ $r_{A3} = 58$ $o_{A3} = 0$	$N_{A4} = 134\ (30/44) = 92$ $n_{A4} = 44\text{-}14 = 30$ $r_{A4} = 18$ $o_{A4} = 0$	$N_{A\cdot} = 438$ $n_{A\cdot} = 376$ $r_{A\cdot} = 267$ $o_{A\cdot} = 0$
I	$N_{I1} = 169\ (164/169) = 164$ $n_{I1} = 169\text{-}5 = 164$ $r_{I1} = 129$ $o_{I1} = 3$	$N_{I2} = 900\ (324/355) = 822$ $n_{I2} = 355\text{-}31 = 324$ $r_{I2} = 239$ $o_{I2} = 11$	$N_{I3} = 166$ $n_{I3} = 24$ $r_{I3} = 18$ $o_{I3} = 0$	$N_{I4} = 546\ (37/39) = 518$ $n_{I4} = 39\text{-}2 = 37$ $r_{I4} = 27$ $o_{I4} = 4$	$N_{I\cdot} = 1670$ $n_{I\cdot} = 549$ $r_{I\cdot} = 413$ $o_{I\cdot} = 18$
G	$N_{G1} = 21\ (20/21) = 20$ $n_{G1} = 21\text{-}1 = 20$ $r_{G1} = 16$ $o_{G1} = 1$	$N_{G2} = 80\ (74/80) = 74$ $n_{G2} = 80\text{-}6 = 74$ $r_{G2} = 61$ $o_{G2} = 0$	$N_{G3} = 5\ (4/5) = 4$ $n_{G3} = 5\text{-}1 = 4$ $r_{G3} = 2$ $o_{G3} = 0$	$N_{G4} = 155\ (52/55) = 147$ $n_{G4} = 55\text{-}3 = 52$ $r_{G4} = 40$ $o_{G4} = 0$	$N_{G\cdot} = 245$ $n_{G\cdot} = 150$ $r_{G\cdot} = 119$ $o_{G\cdot} = 1$
TOTALS	$N_{\cdot 1} = 444$ $n_{\cdot 1} = 444$ $r_{\cdot 1} = 354$ $o_{\cdot 1} = 5$	$N_{\cdot 2} = 1410$ $n_{\cdot 2} = 655$ $r_{\cdot 2} = 475$ $o_{\cdot 2} = 12$	$N_{\cdot 3} = 262$ $n_{\cdot 3} = 102$ $r_{\cdot 3} = 79$ $o_{\cdot 3} = 0$	$N_{\cdot 4} = 820$ $n_{\cdot 4} = 122$ $r_{\cdot 4} = 87$ $o_{\cdot 4} = 4$	$N_{\cdot\cdot} = 2936$ $n_{\cdot\cdot} = 1323$ $r_{\cdot\cdot} = 995$ $o_{\cdot\cdot} = 21$

TABLE 6. Overall View: Universe, Sample, and Response Sizes
After Deletion of Identified Sample Duplicates and Adjustment of Stratum Universe Sizes

where in stratum ij,

N_{ij} = the estimated total universe size for stratum ij.

n_{ij} = the total sample size for stratum ij.

r_{ij} = the number out of n_{ij} sample facilities that responded *with data*, including zeros reported over the telephone, and that *were still in business* at the time of the survey.

o_{ij} = the number out of n_{ij} sample facilities that responded but *were not still in business* at the time of the survey.

NOTE that the total number of respondents in stratum ij is $r_{ij} + o_{ij}$.

Step 7. Estimation

The fundamental setting for sample selection was stratum ij. Thus, the fundamental setting for estimation is also stratum ij. We consider two cases. Actually, Case 2 includes Case 1.

CASE 1: Estimation Consistent With (Along) Stratum Boundaries

Parameters To be specific, let WST_{ij1}, WST_{ij2}, ..., $WST_{ijN_{ij}}$ be the volumes of low level mixed wastes (*llmw*) generated during 1990 by the N_{ij} facilities in stratum ij. Then

- the total volume of *llmw* WST generated during 1990 by the N_{ij} facilities in stratum ij is

$$T_{WST(ij)} = \sum_{k=1}^{N_{ij}} WST_{ijk} \tag{1}$$

and

- the total volume of *llmw* WST generated during 1990 by *all* of the facilities in category i (i.e., $i1$, $i2$, $i3$, and $i4$) is

$$T_{WST(i\cdot)} = T_{WST(i1)} + T_{WST(i2)} + T_{WST(i3)} + T_{WST(i4)} \tag{2}$$

for i = A, G, I, M, and P.

The desire is to estimate $T_{WST(i\cdot)}$ for i = A, G, I, M, and P. Parameters similar to $T_{WST(ij)}$ and $T_{WST(i\cdot)}$ can be defined for other specific *llmw* substances such as SCINT LIQUID, LEADWASTE, etc.

Estimation of $T_{WST(ij)}$ and $T_{WST(i.)}$

We focus on the substance *llmw WST*. Estimators of total volumes for other substances would be similar.

Within stratum ij, we assume that the $n_{ij} - (r_{ij} + o_{ij})$ sample nonrespondents are "missing at random" (Little and Rubin, 1983). According to Little and Rubin (1983), "if the process leading to missing (WST) values (and in particular, the probability that a particular value of (WST) is missing) does not depend on the values of ... (WST), then the missing data are called *missing at random* and the observed data are ***observed at random.***" In such cases, it is appropriate (Oh and Scheuren, 1983; Rubin, 1983; Cochran, 1983; and NAS Panel on Incomplete Data, 1983) to assign sampling weights as follows:

$$w_{ij} = \frac{N_{ij}}{r_{ij} + o_{ij}} = \frac{N_{ij}}{n_{ij}} \left(\frac{n_{ij}}{r_{ij} + o_{ij}} \right) \tag{3}$$

for each of the $r_{ij} + o_{ij}$ respondents.

The sampling weights used are given below in Table 7.

$w_{P1} = \frac{78}{76+0} = 1.0263$	$w_{P2} = 0.0000$	$w_{P3} = 0.0000$	$w_{P4} = 0.0000$
$w_{M1} = \frac{74}{53+1} = 1.3704$	$w_{M2} = \frac{349}{64+1} = 5.3692$	$w_{M3} = \frac{19}{1+0} = 19.0000$	$w_{M4} = \frac{63}{2+0} = 31.5000$
$w_{A1} = \frac{108}{80+0} = 1.3500$	$w_{A2} = \frac{165}{111+0} = 1.4865$	$w_{A3} = \frac{73}{58+0} = 1.2586$	$w_{A4} = \frac{92}{18+0} = 5.1111$
$w_{I1} = \frac{164}{129+3} = 1.2424$	$w_{I2} = \frac{822}{239+11} = 3.2880$	$w_{I3} = \frac{166}{18+0} = 9.2222$	$w_{I4} = \frac{518}{27+4} = 16.7097$
$w_{G1} = \frac{20}{16+1} = 1.1765$	$w_{G2} = \frac{74}{61+0} = 1.2131$	$w_{G3} = \frac{4}{2+0} = 2.0000$	$w_{G4} = \frac{147}{40+0} = 3.6750$

TABLE 7. Sampling Weights

Within stratum ij, assume the raw sample data values are

r_{ij} sample values	o_{ij} sample values
WST_{ij1}	WST_{ij1}
WST_{ij2}	WST_{ij2}
.	.
.	.
.	.
$WST_{ijr_{ij}}$	$WST_{ijo_{ij}}$

NOTE: We take *all* sample values for the o_{ij} respondents to be zeros. (This assumption seems ok if we think "domain estimation" for facilities that are "still in business.")

An estimator for $T_{WST(ij)}$ is

$$\hat{T}_{WST(ij)} = \sum_{k=1}^{r_{ij}+o_{ij}} WST_{ijk} \cdot w_{ij} \tag{4}$$

The estimator $\hat{T}_{WST(ij)}$ is a random variable whose value depends on which sample is selected (and which facilities respond). Thus, $\hat{T}_{WST(ij)}$ has a variance which can be denoted by $Var(\hat{T}_{WST(ij)})$.

An estimator of $Var(\hat{T}_{WST(ij)})$ is

$$\hat{Var}(\hat{T}_{WST(ij)}) = N_{ij}(N_{ij} - r_{ij} - o_{ij}) \frac{S^2_{WST(ij)}}{r_{ij} + o_{ij}} \tag{5}$$

where

$$S^2_{WST(ij)} = \frac{\sum_{k=1}^{r_{ij}+o_{ij}} \left[WST_{ijk} - \bar{WST}_{ij}\right]^2}{r_{ij} + o_{ij} - 1}$$

and

$$\bar{WST}_{(ij)} = \frac{\sum_{k=1}^{r_{ij}+o_{ij}} WST_{ijk}}{r_{ij} + o_{ij}} \quad .$$

NOTE: Again, all sample values for the o_{ij} respondents are zeros. This can be viewed as making estimates of volumes generated in 1990 for facilities still in business at the time of the survey. This changes the definition of the total being estimated slightly.

Hence, an estimator of the ***standard error*** of $\hat{T}_{WST(ij)}$ is

$$\text{s.e. } (\hat{T}_{WST(ij)}) = \sqrt{\hat{Var}(\hat{T}_{WST(ij)})} \quad . \tag{6}$$

It follows that an estimator of $T_{WST(i\cdot)}$, for the i^{th} category facilities, is

$$\hat{T}_{WST(i\cdot)} = \hat{T}_{WST(i1)} + \hat{T}_{WST(i2)} + \hat{T}_{WST(i3)} + \hat{T}_{WST(i4)} \quad , \tag{7}$$

and an estimator of the standard error of $\hat{T}_{WST(i\cdot)}$ is

$$\text{s.e. } (\hat{T}_{WST(i\cdot)}) = \sqrt{\hat{Var}(\hat{T}_{WST(i1)}) + \hat{Var}(\hat{T}_{WST(i2)}) + \hat{Var}(\hat{T}_{WST(i3)}) + \hat{Var}(\hat{T}_{WST(i4)}))} \tag{8}$$

Also, an estimator of $T_{WST(\cdot\cdot)} = \sum_i T_{WST(i\cdot)}$, for all facilities is

$$\hat{T}_{WST(\cdot\cdot)} = \sum_i \hat{T}_{WST(i\cdot)} \quad , \tag{9}$$

and an estimator of the standard error of $\hat{T}_{WST(\cdot\cdot)}$ is

$$\text{s.e. } (\hat{T}_{WST(\cdot\cdot)}) = \sqrt{\sum_i \left[\text{s.e. } (\hat{T}_{WST(i\cdot)})\right]^2} \tag{10}$$

CASE 2: Estimation Not Necessarily Consistent With (Along) Stratum Boundaries: Domain Estimation

It may be of interest to estimate the total volume of *llmw WST* generated during 1990 by a subuniverse (domain) of facilities which does not coincide with the sampling stratum boundaries. For example, if D is the collection of Academic Institutions or the collection of all facilities in the Southeastern Compact, then one may want to proceed as follows to estimate $T_{WST(D)}$ which would be the total *llmw WST* generated in 1990 by all facilities in domain D, say Academic Institutions (that were still in business during the time of the survey). *This method of estimation is also important if there is concern about the extent to which facilities were assigned to incorrect strata in the frame.* As under Case 1, we should first work within stratum ij. An estimator of the total portion of $T_{WST(D)}$ which is in stratum ij is

$$\hat{T}_{WST(D,ij)} = \sum_{\substack{k \text{ over all} \\ D \text{ facilities} \\ \text{in stratum} \\ ij \text{ among the} \\ r_{ij}+o_{ij} \\ \text{respondents}}} (WST_{D(ijk)})\,(w_{ij}) \quad . \tag{11}$$

(See e.g. Cochran (1977), Section 2.13.)

> **NOTE:** Once again, taking all $WST_{D(ijk)}$ sample values for the o_{ij} respondents as zeros, changes the definition of the estimated total volume to those still in business at the time of the survey.

An estimator of the variance (see Cochran (1977), Section 2.13) of $\hat{T}_{WST(D,ij)}$ is

$$\hat{Var}(\hat{T}_{WST(D,ij)}) = N_{ij}(N_{ij} - r_{ij} - o_{ij})\,\frac{S^2_{WST(D,ij)}}{r_{ij}+o_{ij}} \tag{12}$$

where $S^2_{WST(D,ij)} =$

$$\frac{\displaystyle\sum_{\substack{k \text{ over all} \\ D \text{ facilities} \\ \text{in stratum} \\ ij \text{ among the} \\ r_{ij}+o_{ij}}} [WST_{D(ijk)}]^2 \;-(r_{ij}+o_{ij})\left[\sum_{\substack{k \text{ over all} \\ D \text{ facilities} \\ \text{in stratum} \\ ij \text{ among the} \\ r_{ij}+o_{ij}}} WST_{D(ijk)}/(r_{ij}+o_{ij})\right]^2}{r_{ij}+o_{ij}-1} \quad .$$

The estimator of the standard error of $\hat{T}_{WST(D,ij)}$ is

$$\text{s.e.}\,(\hat{T}_{WST(D,ij)}) = \sqrt{\hat{Var}(\hat{T}_{WST(D,ij)})} \quad . \tag{13}$$

Thus, our estimator of $T_{WST(D)}$ is

$$\hat{T}_{WST(D)} = \sum_i \sum_j \hat{T}_{WST(D,ij)} \ , \tag{14}$$

and our estimator of the standard error of $\hat{T}_{WST(D)}$ is

$$\text{s.e. } (\hat{T}_{WST(D)}) = \sqrt{\sum_i \sum_j \hat{Var}(\hat{T}_{WST(D,ij)})} \ . \tag{15}$$

From Table 4.3, $\hat{T}_{(D)} = 28,982$ and s.e.$(\hat{T}_{(D)}) = 3,055$ where D = Academic.

NOTES:

- Actually, all estimators of total volumes can be obtained as described under Case 2. Case 1 was presented first mainly to help the presentation of Case 2.

- If one is only interested in estimating totals such as with $\hat{T}_{WST(D)}$ and not in estimating standard errors such as s.e. $(\hat{T}_{WST(D)})$, then an easy way to view the process in general is to take each respondent's sample value for *llmw WST* and multiply it by its sampling weight and sum all of these products for those sample units in domain D. This gives the same $\hat{T}_{WST(D)}$ described under (14); and when D coincides with strata boundaries, it gives the same result for estimation of a total as would be obtained under Case 1. Recall that taking all sample values for o_{ij} respondents as zeros changes the definition of the total being estimated slightly to the estimate of total volume generated in 1990 by those facilities still in business at the time of the survey.

- One may only want to estimate standard errors only for estimated total volumes at the category level (i = A, G, I, M, and P) or higher due to possibly small sample sizes at lower levels and hence less reliable estimators of standard error. See Table 4.3.

- Assuming that the general estimator $\hat{T}_{X(D)}$ has an approximate normal distribution, then an approximate, say 95%, confidence interval for $T_{X(D)}$, the total volume generated for substance X for some domain D, is given by

$$\hat{T}_{X(D)} - 1.96[\text{s.e. } (\hat{T}_{X(D)})] \ , \ \ \hat{T}_{X(D)} + 1.96[\text{s.e. } (\hat{T}_{X(D)})] \ .$$

References

1. Cochran, W. G. (1977). *Sampling Techniques (3^{rd} Ed)*, Wiley and Sons, New York.

2. Cochran, W. G. (1983). "Historical Perspective," pp. 20-21, in *Incomplete Data in Sample Surveys, Vol. 2*, (W. G. Madow, I. Olkin, and D. R. Rubin, eds.), Academic Press, New York.

3. Little, R. J. A. and Rubin, D. B. (1983). "Missing Data in Large Data Sets," in *Statistical Methods and the Improvement of Data Quality*, (T. Wright, ed.), Academic Press, New York.

4. NAS Panel on Incomplete Data (1983). "Review of Theory," Chapter 5, in *Incomplete Data in Sample Surveys, Vol. 1*, (W. G. Madow, H. Nisselson, and I. Olkin, eds.), Academic Press, New York.

5. Oh, H. L. and Scheuren, F. J. (1983). "Weighting Adjustment for Unit Nonresponse," in *Incomplete Data in Sample Surveys, Vol. 2*, (W. G. Madow, I. Olkin, and D. R. Rubin, eds.), Academic Press, New York.

6. Rubin, D. B. (1983). "Conceptual Issues in the Presence of Nonresponse," in *Incomplete Data for Sample Surveys, Vol. 2*, (W. G. Madow, I. Olkin, and D. R. Rubin, eds.), Academic Press, New York.

APPENDIX F

RECOMMENDATION FOR CHANGES TO SURVEY QUESTIONNAIRE

RECOMMENDATION FOR CHANGES TO SURVEY QUESTIONNAIRE

As outlined in Sect. 1.2.4, twenty members of Appalachian Compact Users of Radioactive Isotopes (ACURI), the association of radioactive licensees within the Appalachian Compact agreed to cooperate in the initial test phase of the national mixed waste survey. Based on the data collected, comments received, and various discussions among the mixed waste profile team members, the pretest survey questionnaire was modified to enhance its usefulness. The final survey questionnaire is included in Appendix B.

However, after receiving over 1,000 responses to the mixed waste questionnaire, we still found that respondents to the questionnaire were able to interpret some of the questions in ways we felt were impossible.

The following are comments or suggestions that the mixed waste profile team are making if any reissuance of the survey is attempted.

GENERAL:

An additional note defining scintillation fluids needs to be added. 'Scintillation fluids with activity both above and below the 0.05 μCi/g level for carbon-14 and tritium are requested. Only information on scintillation fluids containing RCRA hazardous materials such as toluene or xylene is requested.' This clarification could possibly be added under the definition of "Mixed" waste on page i of the questionnaire.

SECTION C

Need to add a statement that a positive answer to C-1, for one or more wastes, should not preclude testing the other LLRW by answering C-2, C-3, and C-4.

SECTION D-1

Add; '**Source** - Process or procedure that produced the waste'.

SECTION D-2

Volume Treated During 1990; Should be worded to indicate the 'amount of the 1990 generated waste that has been treated to date'. also "**treated** (on-site/off-site)" in the directions should be changed to '**treated** (indicate on-site or off-site)'.

SECTION D-3

Need to add a statement that emphasized that the information requested 'included treatment already carried out or expected to be carried out under current conditions'. Should also read "For each mixed waste stream shown as being generated in D-1,'.

Need to add a statement that in general, volume, activity, and effect on the hazard component for incineration are respectively 0, 0, destroyed.

SECTION E-1

Need to add a statement that 'This waste may or may not have been actually generated in 1990.'

SECTION E-1

Add; '**Source** - Process or procedure that produced the waste'.

APPENDIX G

PERMITS AND LICENSES FOR COMPANIES TREATING MIXED WASTES

Appendix G

Permits, Licenses, or Authorizations for Companies Treating Mixed Waste

Exhibit A	List of current and potential future commercial mixed waste treatment facilities.
Exhibit B1	List of permits, licenses, or authorizations pertaining to DSSI.
Exhibit B2	Radioactive materials license for DSSI.
Exhibit B3	Treatment, storage, and disposal permit for DSSI.
Exhibit B4	Air Pollution Control Permit for DSSI.
Exhibit B5	National Emissions Standards for Hazardous Air Pollution Permit for DSSI.
Exhibit B6	Hazardous wastes acceptable for receipt at DSSI.
Exhibit C1	List of permits, licenses, or authorizations pertaining to NSSI.
Exhibit C2	Hazardous waste permit for NSSI.
Exhibit C3	RCRA Part B Permit for NSSI.
Exhibit C4	Radioactive materials license for NSSI.
Exhibit D1	List of permits, licenses, or authorizations pertaining to Quadrex.
Exhibit D2	RCRA hazardous waste permit for Quadrex.
Exhibit D3	RCRA Part B Permit for Quadrex.
Exhibit D4	Radioactive materials license for Quadrex.
Exhibit D5	FDER Used Oil Registration for Quadrex.
Exhibit E1	List of permits, licenses, or authorizations pertaining to RAMP.
Exhibit E2	Radioactive materials license for RAMP.
Exhibit E3	RCRA Part B Permit for RAMP.
Exhibit E4	Hazardous wastes acceptable for receipt at RAMP.
Exhibit F1	List of permits, licenses, or authorizations pertaining to Envirocare.
Exhibit F2	Radioactive materials for license for Envirocare.
Exhibit F3	RCRA permit for Envirocare.
Exhibit F4	Hazardous wastes acceptable for disposal at Envirocare.
Exhibit G	Acceptance limits and criteria for contaminated oils at SEG.

Exhibit A

Current and Potential Future Commercial Industries Treating Mixed Wastes

Company Name and Location	Status of Mixed Waste Treatment Capability	Phone Number
DSSI P.O. Box 863 Kingston, TN 37763	Current	615-376-0084
NSSI P.O. Box 34042 Houston, TX 77234	Current	713-641-0391
Quadrex Corp. 1940 NW 67th Place Gainesville, FL 32606-1649	Current	904-373-6066
RAMP Industries 1127 W. 46th Ave. Denver, CO 80211	Current	303-480-1481
Envirocare Salt Lake City, UT 84111	Planned for future	801-532-1330
SEG P.O. Box 2530 1560 Bear Creek Rd. Oak Ridge, TN 37830	Planned for future	615-481-0222

Exhibit B1

LIST OF PERMITS, LICENSES, OR AUTHORIZATIONS PERTAINING TO DSSI

List of permits, licenses, or authorizations pertaining to DSSI				
Type	**Number**	**Issue date**	**Expiration date**	**Issued by**
Radioactive Materials License	R-73014-H95	August 10, 1990	August 31, 1995	Tennessee Dept. of Health and Environment Division of Radiological Health TERRA Building 150 Ninth Avenue, North Nashville, TN 37219
TSD Type B – Hazardous Waste Permit	TNHW-024	August 4, 1989	August 4, 1999	Tennessee Dept. of Health and Environment Division of Solid Waste Management Customs House 701 Broadway Nashville, TN 37247
Air Pollution Permit	931365-F	August 16, 1991	November 1, 1991	Tennessee Dept. of Health and Environment Division of Air Pollution Control Customs House 701 Broadway Nashville, TN 37247
NESHAP	None specified	April 11, 1989	None specified	U.S. EPA, Region IV Air Pesticides & Toxics Management Division 345 Courtland Street Atlanta, GA 30365
Small Power Production Facility FERC Permit	Docket Number QF-89-280-000	June 22, 1989	None specified	Federal Energy Regulatory Commission Office of the Secretary 825 North Capitol Street, NE Washington, DC 20246
EPA Generators Number	TND 98 210 9142	October 5, 1987	None specified	Tennessee Dept. of Health and Environment Division of Air Pollution Control Customs House 701 Broadway Nashville, TN 37247

Exhibit B2

RADIOACTIVE MATERIALS LICENSE FOR DSSI

STATE OF TENNESSEE
DEPARTMENT OF HEALTH AND ENVIRONMENT
CORDELL HULL BUILDING
NASHVILLE, TENNESSEE 37219-5402

August 10, 1990

Diversified Scientific Services, Inc.
508 N. Kentucky Street
Kingston, TN 37763

Attention: James T. McVey, RSO

Gentlemen:

Attached to this letter is your Tennessee Radioactive Material License numbered R-73014-H95 issued to expire on August 31, 1995.

A copy of 'State Regulations for Protection Against Radiation' referred to in Condition 12 of the license conditions is being sent to you by a separate mailing. Your attention is directed to State Regulations and to specific license Conditions 11 through 27 which are to be followed in the use of this license.

Also attached to this letter are several copies of Form RHS 8-3 for posting as noted on that form.

If we can be of further assistance to you, please contact us.

Sincerely,

Robert N. Young
Health Physicist
Division of Radiological Health

Attachments:

RNY/ry

FORM RHS 8-7
(5-83)

TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT
DIVISION OF RADIOLOGICAL HEALTH

RADIOACTIVE MATERIAL LICENSE

Pursuant to Tennessee Department of Health and Environment Regulations, and in reliance on statements and representations heretofore made by the licensee, a license is hereby issued authorizing the licensee to receive, aquire, possess and transfer radioactive material listed below; and to use such radioactive material for the purpose(s) and at the place(s) desigated below. This license is subject to all applicable rules and regulations of the Tennessee Department of Health and Environment and orders of the Division of Radiological Health, now or hereafter in effect and to any conditions specified below.

LICENSEE	3. License number
1. Name Diversified Scientific Services, Inc.	R-73014-H95
2. Address 508 N. Kentucky Street Kingston, TN 37763	4. Expiration date August 31, 1995
	5. File no. R-73014

6. Radioactive Material (Element and Mass Number)	8. Chemical and/or physical form	9. Maximum Radioactivity and/or quantity of material which licensee may possess at any one time.
SEE SUPPLEMENTARY SHEETS		

10. Authorized Use

SEE SUPPLEMENTARY SHEETS

CONDITIONS

11. Unless otherwise specified, the authorized place of use is the licensee's address stated in item 2. above.

SEE SUPPLEMENTARY SHEETS

Date of Issuance August 10, 1990

For the Commissioner
Tennessee Department of Health and Environment

By: _____
DIVISION OF RADIOLOGICAL HEALTH
Robert N. Young
Health Physicist

TDPH-ORH
PH-0382 Rev 5/83

Form RHS 8-7A
(10-85)

TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT
DIVISION OF RADIOLOGICAL HEALTH

RADIOACTIVE MATERIAL LICENSE

SUPPLEMENTARY SHEET

Page 2 of 8 Pages

License Number R-73014-H95

6. Radioactive Material (Element and Mass Number)	8. Chemical and/or Physical Form	9. Maximum Radioactive Material Which Licensee May Possess at Any One Time
A. Hydrogen 3	A. Any as associated with liquid scintillation type fluids, solutes, solvents, and associated materials.	A. The total combined isotopic activities shall not exceed 10 Curies at any one time.
B. Carbon 14	B. Same as in 8A.	B. See Item 9A.
C. Sulfur 35	C. Same as in 8A.	C. See Item 9A.
D. Chlorine 36	D. Same as in 8A.	D. See Item 9A.
E. Calcium 45	E. Same as in 8A.	E. See Item 9A.
F. Iron 55	F. Same as in 8A.	F. See Item 9A.
G. Iron 59	G. Same as in 8A.	G. See Item 9A.
H. Cesium 137	H. Same as in 8A.	H. See Item 9A.
I. Cobalt 60	I. Same as in 8A.	I. See Item 9A.
J. Cobalt 58	J. Same as in 8A.	J. See Item 9A.
K. Cobalt 57	K. Same as in 8A.	K. See Item 9A.
L. Gadolinium 153	L. Same as in 8A.	L. See Item 9A.
M. Zinc 65	M. Same as in 8A.	M. See Item 9A.
N. Phosphorus 32	N. Same as in 8A.	N. See Item 9A.
O. Phosphorus 33	O. Same as in 8A.	O. See Item 9A.
P. Sodium 22	P. Same as in 8A.	P. See Item 9A.
Q. Rubidium 86	Q. Same as in 8A.	Q. See Item 9A.

Form RHS 8-7A
(10-85)

TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT
DIVISION OF RADIOLOGICAL HEALTH

RADIOACTIVE MATERIAL LICENSE

SUPPLEMENTARY SHEET CORRECTED COPY

Page 3 of 8 Pages License Number R-73014-H95

R. Mercury 203	R. Same as in 8A.	R. See Item 9A.
S. Indium 111	S. Same as in 8A.	S. See Item 9A.
T. Gallium 67	T. Same as in 8A.	T. See Item 9A.
U. Manganese 54	U. Same as in 8A.	U. See Item 9A.
V. Scandium 46	V. Same as in 8A.	V. See Item 9A.
W. Selenium 75	W. Same as in 8A.	W. See Item 9A.
X. Cadmium 109	X. Same as in 8A.	X. See Item 9A.
Y. Nickel 63	Y. Same as in 8A.	Y. See Item 9A.
Z. Copper 64	Z. Same as in 8A.	Z. See Item 9A.
AA. Tin 113	AA. Same as in 8A.	AA. See Item 9A.
BB. Tin 119m	BB. Same as in 8A.	BB. See Item 9A.
CC. Iodine 125	CC. Same as in 8A.	CC. See Item 9A.
DD. Iodine 131	DD. Same as in 8A.	DD. See Item 9A.
EE. Bismuth 207	EE. Same as in 8A.	EE. See Item 9A.
FF. Cerium 141	FF. Same as in 8A.	FF. See Item 9A.
GG. Gold 195	GG. Same as in 8A.	GG. See Item 9A.
HH. Any Radioactive Material with Atomic numbers 1 through 95, inclusive (except U-233, U-235, and any isotope of plutonium)	HH. Sealed Source in plated encapsulated, embedded, or flame sealed (liquid) form.	HH. No single source to exceed 100 microcuries. Total not to exceed One (1) millicurie.
II. Nickel 63	II. Sealed Source (New England Nuclear Model NEN-004)	II. Three (3) sources not to exceed 20 millicuries each.